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Potato production guide

for commercial producers

1986-1987

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EMERGENCY PROCEDURE FOR PESTICIDE POISONING

If you think you have been poisoned TAKE ACTION IMMEDIATELY.

- Find a workmate, neighbor, member of your family or even a stranger and tell them that you suspect poisoning and give details.
- Provide your doctor or hospital with details of the suspected poisoning agent: product name, strength, manufacturer and actual product label.
- Even if poisoning is only suspected, see your doctor or call in at your local hospital for advice.
- Do not take any alcoholic drinks, pain killers or any other medicines.

Medical attention must be obtained as quickly as possible.

ALL HOSPITALS IN ALBERTA ARE POISON CONTROL CENTRES

Emergency Telephone Numbers

Poison Control Centres

University Hospital, Edmonton (Emergency Ward)	432-8432
Royal Alexandra Hospital, Edmonton (Emergency Ward)	474-3431
Calgary General Hospital, Calgary	268-9625
Foothills Hospital, Calgary (Poison Control)	270-1315

Environment Emergency

(Spills, contaminated water, etc.) Call Toll Free: 1-800-222-6514.

Alberta Environment, Edmonton	427-5855

WARNING

No pesticide may be used on any crop or for any use for which it is not registered. Use of unregistered chemicals can result in seizure of the crop. All pesticide products that are recommended in this guide were registered by Agriculture Canada at the time of writing.

The pesticides are listed in this book as a guide to producers. Producers should follow manufacturer's recommendations on the product label.

Copies of this publication may be obtained from:

Print Media Branch
Alberta Agriculture
7000 - 113 Street
Edmonton, Alberta, T6H 5T6
OR
Alberta Agriculture's district offices

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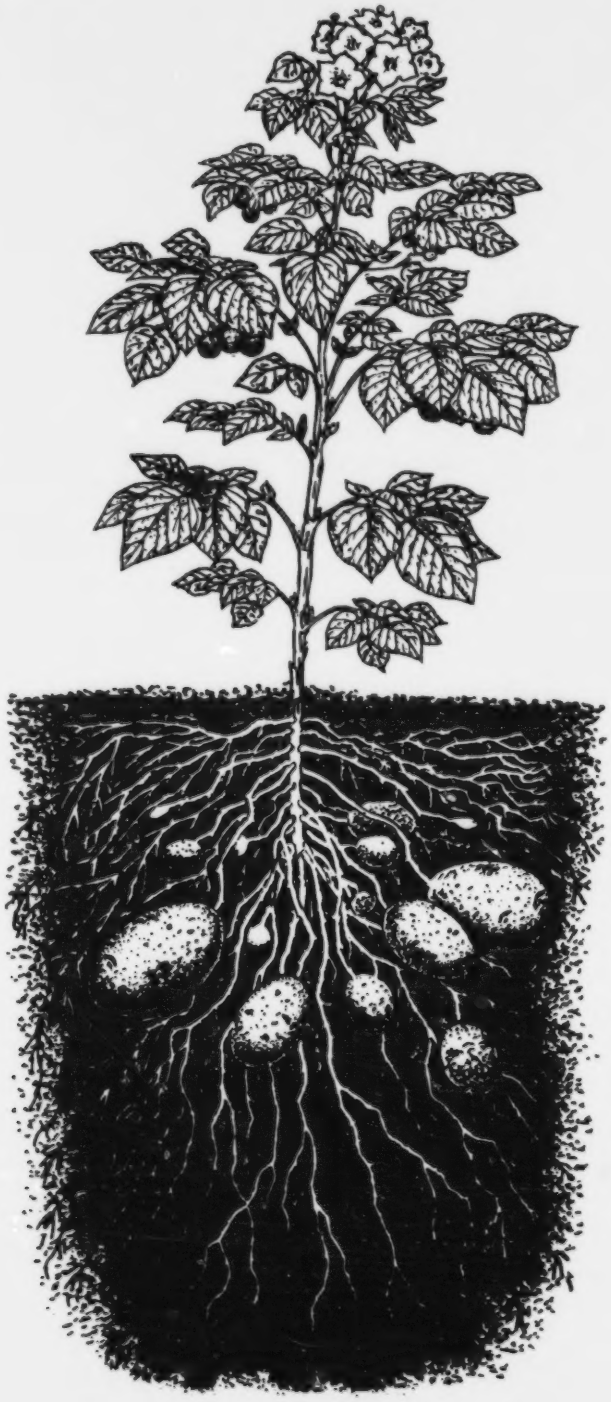
ALBERTA POTATO PRODUCTION GUIDE



Clive A. Schaupmeyer
January 1986
Brooks, Alberta

FOREWORD

Potato production is highly complex, requiring both technical knowledge and management skill. Whether they are produced commercially in small market gardens, or in quarter section fields, the farm operator must apply this knowledge and skill to ensure profitable yields of quality potatoes for the fresh, processing, or seed markets.

This booklet is intended to provide potato producers with much of the technical information they require to plant, grow, harvest, store and market quality potatoes.

Where possible, recommendations are based on both the results of research conducted in Alberta and on the experiences of commercial growers. Several sections deal with general aspects of potato production and soil management that may not apply to experienced growers; however, we feel this information will be useful to those starting a potato production operation, and hopefully serve as a refresher for others.

Measurements are in metric, with the exception that 'acres' are provided in brackets ( ) following the metric term. AMOUNTS OF CHEMICALS ARE GIVEN IN AMOUNT OF ACTUAL PRODUCT unless otherwise noted.

Trade names are used for the convenience of users and the use of specific trade names constitutes neither an endorsement of the product nor a suggestion that similar products are not effective or available.

Many people contributed to this first edition of the Alberta Potato Production Guide. Following is list of the people who wrote major portions of this guide: Dr. Ken Mallett, Dr. Ulf Soehngen, Rudy Esau, Dr. Terry Smyrl, Dr. R. Colin McKenzie, Dennis Darby, Jim Letal, Robert Riewe, Ross McKenzie, Larry Speiss, Jim Carson, Don Laverty, Doug Penney, John Timmermans.

The assistance of all writers and others is appreciated.

Growers who wish more information are invited to contact the appropriate people listed on the back cover of this guide.

This is the first edition of a publication that we hope will be revised every two years. Comments and suggestions that will help improve the second edition are welcomed.

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POTATO PRODUCTION IN ALBERTA

THE HISTORY OF POTATOES

The potato (*Solanum tuberosum*) is an annual plant closely related to black and hairy nightshade, introduced weeds occasionally found in Alberta fields. Other closely related members of the nightshade family (*Solanaceae*) include peppers, eggplants and tomatoes. It is generally agreed that the domesticated potato species originated in the Peruvian and Bolivian Andes of South America and related species were gathered or cultivated for thousands of years before the European explorations. Potatoes were taken first to Spain around 1570 and about 20 years later to England and from these two early European introductions potato production spread to nearly every part of the world. They first reached North America from England in the early 1600's and introductions came from Europe until 1863 when some new lines were brought from Chile.

During the early period of cultivation in Europe, North America and elsewhere, potatoes were grown decade after decade from original tubers and therefore no new cultivars were introduced. Following the Irish potato blight in the 1840's, crossing was increased in North America and many new cultivars were selected in the last half of the century. From this early breeding work the forerunners of modern potato varieties were developed. Common cultivars of 25 to 100 years ago included: Early Rose, Green Mountain, Irish Cobbler, White Rose, Early Ohio, Burbank and Red McLure. Records from Manitoba show that Irish Cobbler, Gold Coin, Netted Gem (Russet Burbank) and Early Ohio were recommended varieties in 1926.

POTATO PRODUCTION IN ALBERTA

Records of potato production in the early history of Alberta are scarce, but it is presumed small scale potato production in home and market gardens was common place as areas of Alberta were settled and developed. On October 3, 1810, Daniel Harman, the Factor for the North West Trading Company post in Dunvegan, wrote, "...we harvested the potatoes that were planted on May 10 and found the nine bushels planted produced 150 bushels...". By the 1930's commercial potato production was well established and records of the Western Canadian Society for Horticulture show that there were 2,400 hectares (6,000 ac) of irrigated potatoes grown in the Lethbridge area in 1937. It was a record year and the crop averaged 16 t/ha (6.3 t/ac). During the 1930's and 1940's certified seed production and grading regulations were implimented and table stock quality improved. In the early part of the 1940's the industry was severely cut back by an outbreak of bacterial ring rot which damaged established export markets. By the mid 1950's quality, markets and credibility had been re-established and Alberta potatoes received good publicity with their performance at the Toronto Royal Agricultural Fair. The best account of early potato production in Alberta is recorded in "Development of Horticulture on the Canadian Prairies", compiled by the Western Canadian Society for Horticulture in 1956.

During the past two decades major changes have been made in the mechanization, storages, packaging facilities and in processing. The following table shows the area, production and average yield for Alberta from 1976 to 1985. (Table 1).

Of the 9644 ha (23,800 ac) produced in 1985 approximately 33% were designated as table stock, 17% as seed stock and 50% for processing.

THE POTATO PLANT AND TUBERS

The potato tuber is an enlarged portion of an underground stem called a rhizome or stolon: it is not a root (Figure 1). The tubers enlarge at the tips of the underground stems and the eyes that form on the tubers are similar to buds that form on the branches - buds from

Table 1. Potato Production 1976-1985

Year	Number of Growers	Area ha (ac)	Production (tonnes)	Average Yield (t/ha)
1976	232	6,40[illegible] (15,801)	121,700	7.7
1977	210	6,260 (15,472)	159,900	10.3
1978	205	6,100 (15,069)	133,700	8.9
1979	196	6,370 (15,735)	132,300	8.4
1980	198	6,200 (15,308)	147,800	9.7
1981	192	6,660 (16,443)	143,300	8.7
1982	197	7,485 (18,490)	185,600	10.1
1983	195	7,610 (18,800)	209,100	11.1
1984	205	8,360 (20,656)	214,000	10.4
1985	166	9,640 (23,820)	220,000	9.2 (est)

Note: Weights in this publication are in metric. The abbreviation "t" is for tonnes.

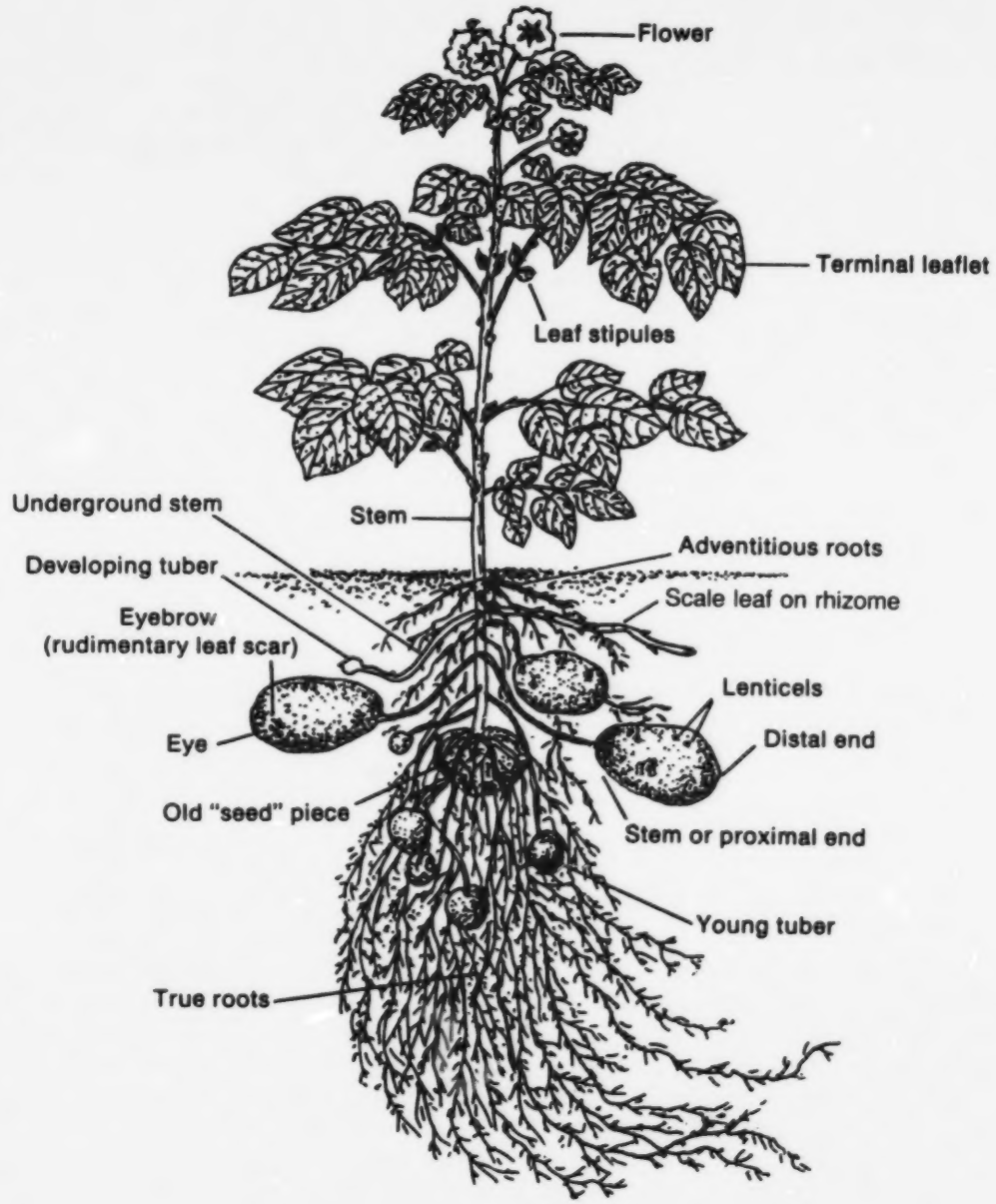


Figure 1. Diagram of potato plant.

which next season's growth will sprout. The eyes are concentrated near the tip (distal) end of the tuber and are less concentrated near the stolon or stem end. The tuber skin is comprised of two layers of cells: a layer of single cells called the epidermis, and several layers of corky cells called the periderm. It is the cells in the periderm layer that may be colored with reddish pigment to produce red-type potatoes. The epiderm and periderm form the "skin". Next to the periderm is the cortex followed by the vascular ring which contains cells that transport food products to the tuber from the above ground stems. The internal part of the tuber is called the medulla and this is the part of the tuber that contributes to the bulking of potatoes. Excess food produced by the potato plant is transported to the medulla via the vascular ring and the cells in the medulla increase in number and size as they are supplied with food (Figure 2).

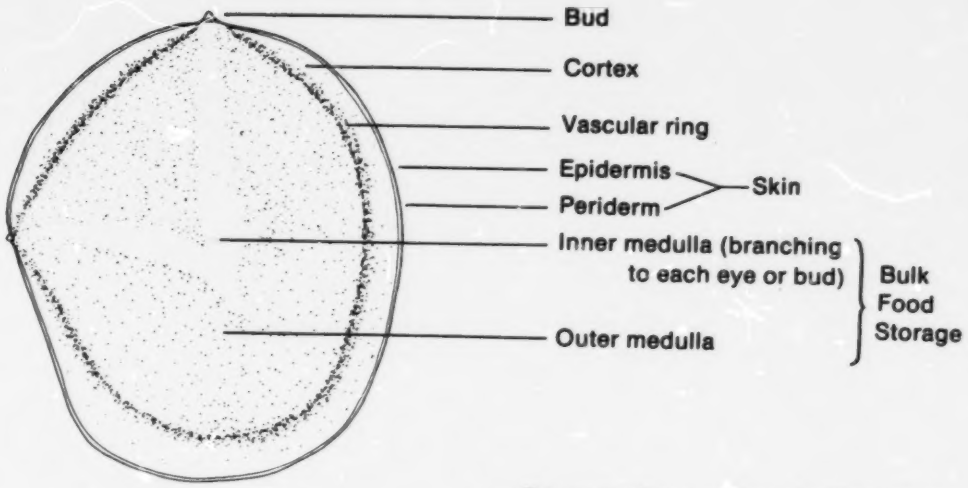


Figure 2. Cross section of potato tuber.

POTATO PLANT GROWTH

The growth and quality of potatoes are influenced by environmental factors such as temperature, moisture, light and soil. Those contemplating commercial potato production, as well as those growers already involved, should be aware of how potatoes develop and grow and how soil temperature, moisture and light influence production.

Plants and animals grow by increasing their cell numbers and cell size. Cells rapidly increase their numbers in meristematic areas such as shoot and root tips, plus in the cambium region of stems and branches. The effects that light, temperature, water and nutrients have on cell numbers and cell division are uncertain. Knowledge of plant structure and growth, and the effect of environmental factors on growth is useful in determining cultural practices.

Potato specialists in Washington have identified 17 factors which influence the growth of potatoes. These include: length of growing season, air and soil temperatures, light intensity and duration, humidity, wind; all of which are largely uncontrollable by the grower. Other factors can be controlled by the grower. These are: moisture, insects, diseases, days grown, fertility, seed quality, seed size, plant stand, timely operations, and cultivar selection. Only when all factors are at optimum levels can high yields be achieved. In Alberta we could expect the upper limits of yield to be about 60 t/ha (25 tonnes/ac) given optimum inputs and ideal environmental conditions. Growers occasionally, but not consistently, have achieved yields as high as 50 t/ha (20 tonnes/ac) in the past few years.

Temperature. The potato is a cool-season crop. Yields are highest when average daytime temperatures are lower than 21°C. Cool night temperatures are even more important than cool daytime temperatures, since cool night temperatures are associated with an accumulation of carbohydrates and dry matter in the tubers. At lower night temperatures, the plant's respiration process is slowed and less dry matter is burned up. Thus, at lower night temperatures a greater proportion of the dry matter accumulates and is stored in the tubers as starch. The optimum temperature for initiating tubers is 16-19°C. Tuber development is reduced above 20°C and practically stops at temperatures of 30°C or above.

Emergence of seedlings from seed pieces is more rapid at higher temperatures. Very little sprout elongation occurs at 6°C, elongation is slow at 9°C and about optimum at 18°C. The number of tubers per plant is greater at lower temperatures than at higher temperatures, whereas higher temperatures favor large tubers. Second growth of tubers, associated with irregular moisture levels, can also develop under high temperatures. This occured in July 1985 in southern Alberta when temperatures in the tuber zone approached 30°C and second growth was common in Russet Burbank fields.

Moisture. Potatoes require a continuously available supply of soil water in the presence of good soil aeration. Yields are greatest when soil moisture is maintained in the upper half of the available range (see irrigation section). Excess moisture can result in poor aeration and water logging, which will reduce root growth and yields. An excess of moisture may also lead to enlarged lenticels or openings of the skin which detract from the appearance of

the tubers. The amount of water needed by potatoes will vary with the amount of fertilizer used, the soil type, temperature, air movement and cultural practices. Water soaked soil at harvest can cause bitterness of Russet Burbank tubers. This also occurred in 1985 and was aggravated by cold stress.

Light. Intensity and duration of light affect potatoes. When light intensity is high, tuber initiation and development start earlier, maximum stem length is reached earlier, yields are higher and tubers contain more dry matter than at lower light intensities. However, at very high light intensities the plant may die earlier and tuber weight may be limited by this early senescence. When the duration of light is long, vegetative top growth, particularly stem elongation is enhanced; but when light periods are shorter, stolons are shorter and the rate of tuber set increases.

TUBER INITIATION AND GROWTH

Tuberization or tuber initiation refers to the time at which tubers begin to swell at the end of rhizomes. This usually occurs from about mid-June to mid-July in Alberta depending on location, planting date, climate, soil type, and cultivar. The tubers form when the plant produces more carbohydrates than are required for vine growth. Varying conditions can affect the plants, or cause a carbohydrate deficit, and uneven tuber formation can occur. The number of tubers to form per plant is referred to as tuber set. Early in the year 15 or 20 small tubers may form; however, only 5-10 mature tubers are normally found in each hill at harvest. It is believed that the many small tubers that are initially set are used by the growing plant or absorbed into larger tubers.

Optimum moisture and nutrient levels are therefore critical to the maintenance and development of tubers very early in the growing season. The effect of uniform high levels of moisture has been well documented in Alberta. (See Irrigation section). Maintaining high levels of moisture (above 60% available moisture) has been shown to produce high tuber set and development compared to lower moisture levels.

Uneven growth of the potato plant and therefore uneven growth of tubers can result in tuber abnormalities. Fluctuating temperatures, moisture, and nitrogen, especially in the tubers' formative stage, can cause these malformed tubers. Tubers that have set may in fact disappear if carbohydrates (food) are required by the plant faster than they are produced.

PRODUCING PROFITABLE YIELDS OF QUALITY POTATOES

The object of all potato growers is to produce profitable yields of quality potatoes. Yield is important because it affects gross income; quality is important because the potatoes must be marketable. Production inputs which promote high yields may or may not promote quality and producers must often decide to manage a crop so that they do not necessarily achieve maximum yield in order to achieve maximum quality. The following is a brief summary of the major factors the producer can manipulate to achieve an optimum yield. More detailed discussion of these practices is presented in subsequent sections.

Marketing. A crop can only be profitable when it is sold. It is imperative that growers produce to suit a projected market, not market to suit production.

A slight majority of potatoes produced in Alberta are sold to processors for French frying and chipping and all of these are grown under contract. Many fresh market growers produce potatoes for specific packers, although they may not sign a contract they discuss market agreements early in the crop year. Prospective seed growers need to be aware that their credibility and reputation as a supplier of quality potato seed may take several years to establish.

Producing a reasonable tonnage of potatoes is not necessarily a difficult task and new growers are often surprised at the actual quantity of potatoes that can come from a field. Provisions for low-waste harvesting, handling, storage and marketing must be made in advance of production. New growers who wish more information on processors, fresh packers and marketing in general are invited to contact The Alberta Potato Commission, Suite 244, Stockman's Center, 2116 - 27 Avenue, N.E., Calgary, Alberta, T2E 7A6 (phone 403/291-2430). All potato growers producing more than 0.4 ha (1 ac) or more of potatoes are required to be licensed by the Alberta Potato Commission and new growers should contact the APC office for this licence.

Site Selection. In choosing a site for a potato farm the prospective producer has to be aware of two general factors: climate and soil. Generally potato production should be confined to those areas shown on the accompanying climate map with 100 or more frost free days (Figure 3). Certain micro-climates outside of this zone, such as river valleys, may be suitable; conversely, some small areas within the 100-day-or-more zone may be subject to abnormal frosts. The areas with longer frost free periods have the potential to produce the highest yields, however other factors such as availability of irrigation water, soil and nearness to markets have to be considered. A long frost free season allows the grower a wider choice of cultivars, a longer harvest period and generally contributes to the production of high yields of well matured potatoes.

Deep, well-drained, coarse textured soils such as loamy sands, sandy loams and loams are the best soils for potato production. Coarse textured soils tend to warm up sooner

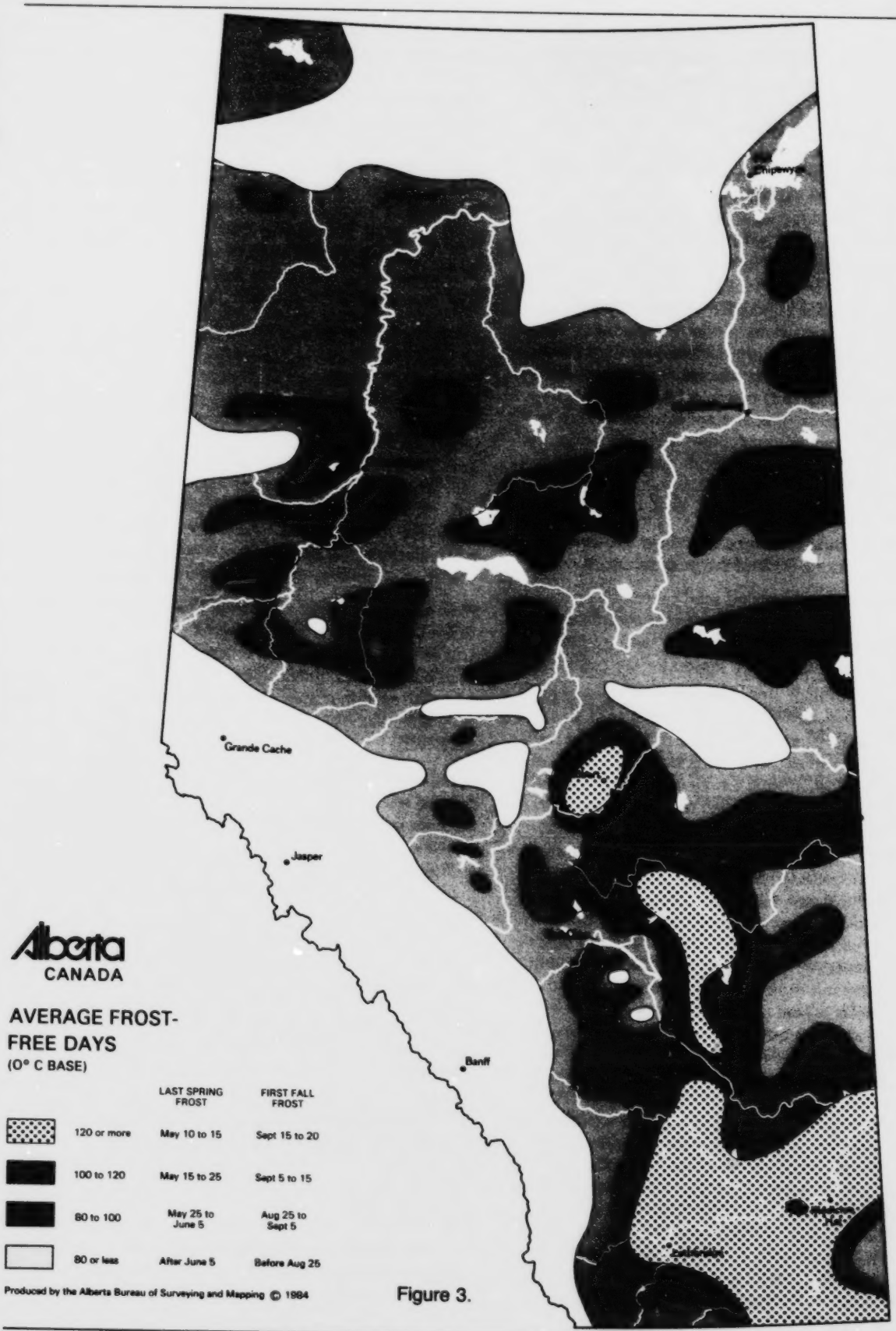

Grande Cache
Jasper
Banff
Alberta
CANADA
AVERAGE FROST-FREE DAYS
(0° C BASE)
LAST SPRING FROST
FIRST FALL FROST
120 or more
May 10 to 15
Sept 15 to 20
100 to 120
May 15 to 25
Sept 5 to 15
80 to 100
May 25 to June 5
Aug 25 to Sept 5
80 or less
After June 5
Before Aug 25
Produced by the Alberta Bureau of Surveying and Mapping © 1984

Figure 3.

in the spring, are easily worked and have good drainage which allows them to dry out if necessary prior to harvest. The major concern with very coarse soils (sands) is their low water-holding capacity, and they generally will require irrigation water in most parts of Alberta to produce consistent yields of quality potatoes. Finer textured soils with high amounts of clay can be difficult to work into a clod-free seed bed and they become sticky when wet or lumpy when dry. Clay soils adhere to tubers and they may require considerable washing. Poorly drained soils can result in delayed tillage or harvest operations and potatoes may be subject to an increase in disease.

Cultivar and Seed Selection. Cultivars are described in detail in section two. New producers need to become familiar with varieties so they can select the best ones for their market and climate. Varieties are commonly described by their maturity (early, mid, late), skin color (white, buff, red), skin texture (smooth, russetted, netted), flesh color (white, cream, yellow), flesh texture (dry, mealy, wet), and tuber shape (round, oval, oblong, long).

There are about 25 cultivars grown in Alberta; however, eight account for nearly 98% of the crop produced.

The importance of using certified seed cannot be over-emphasized. Whereas the primary reason for certification of many crops is to ensure genetic purity (also a factor in potato certification), the primary reason for the potato certification program is to maintain disease-free production. Because potatoes are grown from fleshy tubers, a large number of bacterial, fungal and viral diseases can be carried over from generation to generation. If these diseases were left unchecked, production of potatoes would soon be impossible. Many diseases merely reduce plant vigor and yield, but others given the right conditions will kill the crop.

The Canadian potato seed certification program relies on many groups to maintain excellent quality seed for Alberta growers: disease freeing of tubers is done by Agriculture Canada: early generation seed stock for seed growers is supplied by Alberta Agriculture: certified seed is produced by seed growers; and Agriculture Canada inspects and certifies seed fields. There are five levels of commercially available seed each representing one generation: Elite I, Elite II, Elite III, Foundation and Certified. An elite seed grower receives pre-Elite seed from Alberta Agriculture's seed program at Olds. From this is produced Elite I seed stock. This is planted the following year, and subsequently after five years certified seed is produced. There are no levels of certification beyond "Certified" therefore all certified seed is maximum of five generations away from a completely disease-free source. This flush-through system helps maintain a supply of quality seed for Alberta potato producers. The use of certified seed is imperative if commercial growers are to maintain high yields of quality potatoes.

Planting. Two factors are paramount to a potato crop: stand and vigor. Establishing a high stand of uniformly vigorous seedlings is a demanding practice and no amount of other cultural inputs, like fertilization, irrigation and pest control, will compensate for a poorly planted crop. Potato plants adjacent to a "miss" will have an increased yield but the increase does not make up for the zero yield of the missing plant. Potato producers achieve good stands by maintaining and operating their planters properly and by cutting uniform seed pieces. Small slivers or diseased seed may be planted, but resulting seedlings will be weak or die.

Plants must be vigorous and strong to produce high yields. Large, uniform seed pieces with few cut surfaces produce strong plants. The average seed size should be a minimum of 50 g with only a few pieces less than 50 g. Because seed piece sizing is so important, good potato producers start with uniform seed tubers ranging from 100-200 g in size. Large seed tubers produce a seed lot with a high proportion of pieces with two, three and even four cut surfaces and these pieces are not as productive as single cut pieces or small whole tubers. A seed lot that is not uniform in size and shape will produce seed pieces that are not uniform and therefore more difficult to plant.

Most top-yielding potato growers treat the cut seed lot with a registered treatment to reduce seed piece decay. Cut seed is usually planted within a day of cutting and kept out of the sun and drying wind to prevent moisture loss. Cut seed that must be stored is suberized in warm humid conditions to promote rapid healing of the cut surface.

Fertility and Irrigation. The coarse textured, well-drained soils used for potatoes will require adequate amounts of nutrients to produce profitable yields and growers are urged to soil test annually. Typically, nitrogen and phosphorous are the two nutrients applied to potatoes, although potassium may sometimes be recommended. Potatoes forage for nutrients and water to a depth of about 80 cm, therefore soil sampling to at least 50 cm is recommended to get a more accurate nitrogen reading. A full complement of nutrients is required to produce a high yield of quality potatoes; however it must be stressed that over application of nitrogen can delay maturity by up to 15 days which is obviously critical in Alberta's short season.

Irrigation in central or northern Alberta is good insurance in most years, and mandatory every year in southern Alberta to produce high yields. A uniform supply of moisture (above 60% of available moisture capacity) generally increases tuber set and yield, and reduces the number of culls.

Pest Management. Diseases, insects and weeds can ravage potatoes if left unchecked. New growers must become familiar with pests if they expect to grow quality

potatoes and make a profit. The importance of pest management is best stressed by reflecting on the seed potato program in Alberta and in Canada. A handful of tubers that are completely disease free are released by Agriculture Canada, propagated by Alberta Agriculture and then go through five vigorous years of growing and inspection on seed farms before it is made available as certified seed for commercial growers. This whole process is aimed primarily at disease control. The best tool available to the commercial grower to control disease is "Certified Seed". He/she also needs to be concerned about seed piece decay, early blight, and storage diseases like soft rot and dry rot. Bacterial ring rot, which has nearly disappeared in Alberta, will always be a major concern because it is highly contagious and destructive if left uncontrolled. All potato fields in Alberta are inspected for ring rot every year.

Insects like the Colorado potato beetle can completely defoliate a potato crop if left unchecked. Wireworms, which are ever present in newly broken land, cause unsightly tunnels in tubers which can result in losses on the grading line or even reduction in grade if damage is severe. Seed growers need to control aphids to prevent the spread of viruses that may cause loss of certification.

Weed control in potatoes is not normally a problem as the combination of cultivation and herbicides is usually quite effective. New row-crop growers will soon find out what established growers have known for a long time: a few weeds left unchecked in the spring become an unmanageable mess by fall. Severe weed infestations reduce yields, interfere with harvest and are a bountiful seed source for subsequent crops.

Harvest Management. Getting a bumper crop of potatoes to market or into storage while maintaining excellent quality involves planning and good management. Vine killing is usually done 10 days or more prior to harvest to ensure a good skin set and reduce skininng. Harvest equipment must be in good working order and personnel must be trained. Harvesters must be operated so that bruising is kept to a minimum. Bruises, cuts and scrapes are typically caused by roll-back, drop and sharp edges on harvesters; all of which can be reduced by machinery modification, chain speed reduction and maintenance. (A new VHS video on harvester management is available from the Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta, T0J 0J0 (phone 403/362-3391). It shows how a harvester must be adjusted and maintained and is useful both for growers and their staff).

Storage Management. Seed must be stored for eight months, through to the next crop year, without rotting or sprouting. Potatoes for french frying and especially chipping must maintain low levels of sugars in order that they produce light colored frys or chips. These seem like impossible tasks to the unfamiliar, but they are done every year by experienced growers with good storage and sound management.

Obviously a grower must place a good quality crop into storage to take a good one out. "Garbage in: garbage out" applies to fresh produce storage. Grower management throughout the season (cultivar selection, seed cutting, planting, fertilization, irrigation, pest control and harvest management) all contribute to the quality going into storage. Unfortunately in 1984 and 1985 many growers were faced with an uncontrollable factor which affected storability of their potatoes: cold freezing weather during harvest in late September and early October. But many growers found that by heavy culling and by cunng the potatoes with relatively high volumes of air they were still able to keep a problem crop for a reasonable amount of time.

Sanitation of storages and equipment helps reduce losses due to disease. Maintenance of proper temperatures, humidity and airflow prevents heat buildup and rots, reduces shrink to a minimum, and maintains processing quality. To do all of this, growers require facilities that provide the necessary controls.

POTATO QUALITY

Nutritional Quality. Potatoes have long been recognized as a non-fattening, nutritious and wholesome food which supplies many important nutrients to the diet. On average, potatoes contain 78% water, 22% dry matter and less than 1% fat. Approximately 82% of the dry matter is carbohydrates, which occur mainly as starch; however, some sugars are also present in varying amounts. The starch content is closely correlated with the specific gravity of the tubers and starch is the most important component from a caloric point of view. Potatoes contain 11% protein by dry weight, which is less than that of soybeans, however the nutritional quality of potato proteins is better than that of soybeans. At least 12 essential vitamins and minerals are furnished when potatoes are included in the diet. Potatoes are a very economical source of vitamin C and contain thiamine, iron, folic acid and some fibre. The food value of potatoes is dependent upon many factors such as, soil type, fertility, moisture, growing environment and processing.

Fresh Market Quality. Good quality is the most important factor influencing saleability and preference for a particular product. Good quality potatoes should be clean, uniform in shape and size, and have a unmarked skin, firm flesh, and shallow eyes. Because of wastage in home-trimming operations, potatoes with deep eyes and many surface defects are not looked upon favorably by the consumer. In addition to these quality characteristics, other tuber defects which may adversely influence the decision of the consumer to purchase the product are

sunburn, greening, second growth, growth cracks, scab, storage rots, black spot, skinning, bruising and mechanical damage. The use of transparent packaging material for potatoes on the retail market has increased the confidence of the consumer in the product since the product can be easily evaluated prior to purchase. Transparent packages do contribute to greening of tubers in retail stores.

In addition to physical quality and appearance, potatoes must also have good cooking and eating quality. The main culinary quality factors associated with home-prepared potatoes are texture, color, flavor and odor.

The texture of cooked potatoes is directly related to the dry matter content or the specific gravity, and is described as mealy and dry or soggy and wet. Potatoes such as Russett Burbank, that have a high dry matter content, usually have a mealy texture with the desired flakiness when properly baked; however, these potatoes may slough or break up when boiled. Potatoes such as Norland, with lower specific gravities are inclined to be soggy and wet when baked, but hold their form quite well when boiled.

White-fleshed potatoes when boiled or baked are expected to be a creamy white color. Yellow fleshed varieties should retain their characteristic yellow color during cooking as well. Tubers which have been exposed to light during growth, harvest or storage may have developed a green color in the skin which extends into the flesh. This greening is due to the light induced formation of chlorophyll and although the greening does not adversely affect the cooking quality or nutritional value of the potato, it is objectional to the consumer from an aesthetic point of view. It may also be an indication that the potatoes are bitter. White or yellow-fleshed potatoes should exhibit minimal after-cooking darkening.

This darkening, which is often more prevalent at the stem end of the tuber, is believed to be due to dark pigment formation resulting from the reaction between chlorogenic acid and iron, which are both natural constituents of the potato. Research at the Agriculture Canada Research Station, Lethbridge, has shown that Russet Burbank potatoes grown in the central part of the province had significantly higher chlorogenic acid contents than their southern counterparts.

Varieties such as Norland, which naturally contain higher amount of chlorogenic acid, blacken more than varieties containing less chlorogenic acid, for example, Norchip, Russet Burbank, and Norgold Russet. Another naturally occurring potato constituent, citric acid, moderates the after-cooking darkening to a degree since it has been found that potatoes with higher levels of citric acid exhibit less after-cooking darkening than potatoes with lower levels of citric acid. In the home, after-cooking darkening may be controlled with lemon juice (which contains citric acid). In the commercial potato processing industry sodium acid pyrophosphate is used.

Cooked potatoes are expected to have the flavor and aroma normally associated with the product, without off-odors or off-flavors. One group of chemicals in potatoes which contribute to the characteristic potato flavor when present in small amounts, are alkaloid compounds, such as solanine and chaconine. Collectively these compounds are referred to as total glycoalkaloids or TGA's. TGA's are naturally present at low levels (2-15 mg/100 g fresh tuber weight); however, when TGA levels increase to 15-20 mg/100 g the potatoes are very bitter when eaten, and at levels above 20 mg/100 g, the potatoes are considered unfit for human consumption owing to the toxic nature of the glycoalkaloids. The development of bitterness in potatoes is often signalled by surface greening of the tubers although the synthesis of bittering compounds and green color development are totally independent phenomena. It has been mentioned previously that when potatoes are exposed to light, the green pigment chlorophyll will form; this same light also triggers chemical reactions in the outer layer of the potato tuber leading to increased TGA levels. Light green potatoes are harmless if peeled. Moderately green tubers should not be utilized for consumption without first taste testing the outer 3 mm of several raw tubers.

Bitterness or burning indicates TGA levels that are too high and the potatoes should be discarded. Sunburned potatoes (distinct dark green patches diffused with bronze or purple) should be disposed of immediately. Elevated TGA levels in potatoes may result not only from exposure to light but from harvesting immature potatoes, bruising, skinning and improper temperature control. Wet conditions prior to harvest, and chilling or freezing may also cause high TGA levels. Cold potatoes should be slowly warmed up to 15°C for 10 days after harvest and before the temperature is reduced for long-term storage. Unlike other problems associated with potato quality, such as after-cooking darkening, TGA accumulation cannot be counteracted with chemicals or special processing techniques. Glycoalkaloids do not leach from potatoes into blanching or cooking water, nor are they destroyed during the high temperatures associated with boiling, baking or even deep frying.

Quality of Pre-peeled Potatoes. A portion of the potato crop (sometimes cull material) is devoted to the production of pre-peeled product for the food service industry. These potatoes are peeled by chemical, heat or abrasion techniques. Following peeling and trimming, the potatoes are packed for shipment to user or distributor. These pre-peeled potatoes must be refrigerated at all times since they have a limited shelf life. It is common practice to treat the potatoes with sulfites or bisulfites before packaging to prevent enzymatic browning. Because large tubers have less peel per unit weight of flesh, they have lower peeling and trimming losses when processed.

Uniformity of shape and size are necessary for efficient peeling, especially when abrasion peelers are used. As well, the presence of rot, surface cuts and bruises increase trimming losses.

Potato Chip Quality. Four important factors which must be considered in the production of high quality chips are: yield of chips from a given quantity of fresh potatoes, color of chips, oil content of the product and chip flavor.

Thus when a processor receives a load of potatoes, certain desirable characteristics are looked for. One of the most important is specific gravity. The yield of potato chips increases as the specific gravity of the fresh potatoes increases. Deep frying of potato slices to chips is a water removal process, hence the higher the water content of the potato the more water will be lost to evaporation. On the other hand, potatoes with more solids (higher specific gravity) will lose less water per unit weight and, consequently, product yield increases. Some factors which influence specific gravity are cultivar, maturity, fertility, irrigation, and storage conditions. In addition to its influence on production yield, specific gravity has a direct bearing in the amount of oil absorbed by the potato slices during the deep frying process. Slices from low specific gravity tubers absorb more oil than slices from high specific gravity tubes. Some oil absorbtion by the potato slices during deep frying is desirable for flavor development; however, too much oil absorption represents a direct loss of an expensive processing commodity to the processor, and chips with excessively high oil contents will be perceived as greasy and oily by the consumer.

Color is a very important quality characteristic of chips. Consumers normally expect light colored chips with little vascular discoloration. Even though the processor does have some control of chip color (manipulation of oil temperature, slice thickness and length of frying period), it is difficult because the color of the potato chips is largely determined by the chemical composition of the potato tuber. The degree of darkening which develops in chips during deep frying is closely associated with the level of reducing sugars (glucose and fructose) in the tuber. During the time in which the potato slices are exposed to high temperatures during frying, the reducing sugars react with proteins and amino acids to form dark products in the Maillard or non-enzymatic browning reaction. The concentration of chemical constituents, such as reducing sugars, depends on many factors including variety, growing conditions, maturity, and storage conditions.

It is important that potato chips possess a pleasing and desirable flavor. Thus potatoes should not have bitterness or other off-flavors. The flavor of potato chips is more complex than that of boiled, baked or mashed potatoes, since the cooking temperatures are much higher, and the absorbed oil contributes to the overall flavor profile of the product.

French Fry Quality. Good quality french fries have a uniform light cream to golden color. They have a good potato flavor free from rancidity, bitterness, and are free from scorched taste and off odors. Their texture consists of external surfaces that are moderately crisp, showing no separation from the inner portion. The inside is tender, mealy and free from sogginess. Other defects which influence appearance, such as sunburn, carbon spots and light and dark brown areas, are not desired.

As in the case of potato chips, the color of french fries also depends on the reducing sugar content of the potatoes; however, the french fry processor has more control of reducing sugar levels caused by the blanching process. Mealiness, crispness and lack of oiliness of french fries increases with specific gravity.

PRODUCTION MANAGEMENT

The importance of producing profitable yields of quality potatoes has been stressed. This section and the following sections try to provide information on methods that will help growers achieve these optimum yields. Growing a crop of potatoes that pays most of the bills can be relatively easy: growing a good crop of potatoes that returns a profit requires the application and understanding of the best production methods available.

This section discusses cultivar description, seed cutting, planting, plant growth, tuber setting and development, field sprout inhibition, top killing and harvest management. Soil management, fertilization, irrigation and pest management are presented in other sections.

CULTIVARS

CULTIVAR SELECTION

Processing. Cultivars for processing will be specified in the grower/processor contract. The french fry industry requests either Russet Burbank or Shepody (a new fryer that has replaced some Russet Burbank for early season processing). Chip processors request Superior for early out-of-the-field chipping, and Norchip for their mid-season and out-of-storage needs.

Fresh Market. The main fresh market cultivars grown in Alberta are Russet Burbank (late), Norgold Russet (mid), Norland (early-mid red), Sangre (late red). Superior (primarily a chipper) is popular with some growers as an early round white variety. Carlton also an early round white, is preferred by a few growers. Yukon Gold is a new mid-season cultivar with yellow flesh that is gaining some popularity with growers for a currently limited yellow-fleshed market. Approximately 14 other cultivars are grown for the fresh market but the total area is very small and growers select these types because of personal preference, local growing conditions, or for specialized markets.

Although Russet Burbank is a popular fresh market cultivar new growers must be aware that it is late maturing and yield and quality can be poor in areas with a shorter growing season. Norgold Russet is an earlier russet type potato that may be considered in areas where climate is a limiting factor.

Seed Production. The demand for potato seed is directly related to the area of commercial potatoes produced and seed growers needs to base their production on established cultivars. However, from time-to-time they may wish to speculate on the acceptance of new potato cultivars. A few promising new cultivars are licensed every year based on research data, grower trials and industry acceptance. In the long run, few of the varieties that are licensed become firmly established with a sizable production area and therefore a significant seed market. Sometimes a seed grower's efforts at producing new cultivars will be lost, but these losses can be overcome with profits made from production of seed of a suddenly popular cultivar. Sangre and Shepody are examples of cultivars that have gained industry acceptance very quickly and unless some unknown flaw appears, they will be significant cultivars cutting into current Norland and Russet Burbank area. Demand for seed of these two cultivars was great in 1985, and growers who started seed production early were well paid. Seed growers need to be aware of industry developments to take advantage of examples like this.

CULTIVAR DESCRIPTIONS

Eight cultivars accounted for 9,400 ha (23,200 ac) or 97.6% of the area planted to potatoes in Alberta in 1985. The other 250 ha (2.4%) consisted of 15 cultivars. Other cultivars grown in Alberta include: Yukon Gold, Atlantic, Viking, Pontiac, Centennial Russet, Bintje, Monona, Warba, Crystal and others. Of these, Yukon Gold, a round, yellow-fleshed variety is becoming more popular as a fresh market potato. Following is a detailed description of the eight leading cultivars. Figure 4 shows

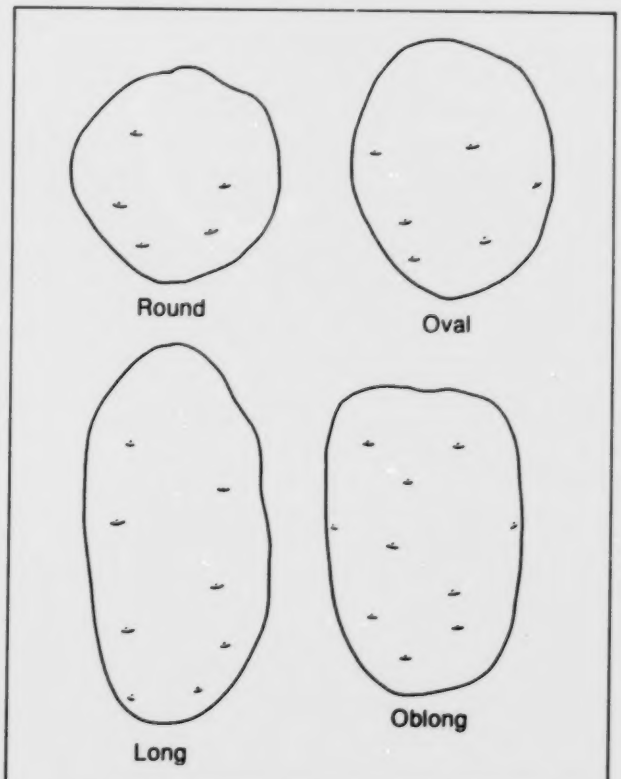


Figure 4. Shapes used to describe potato varieties.

the shapes used to describe potato cultivars. Seven of the eight most commonly planted cultivars are shown on the color plate.

RUSSET BURBANK

PRIMARY USE French fry
SECONDARY USE Fresh market. Good baking and boiling
MATURITY Late (120 days)
TUBER: **SHAPE** Long, slightly flattened
EYES Numerous; acceptable
SKIN COLOR Tan
SKIN TEXTURE Russeted, netted
FLESH COLOR White
FLESH TEXTURE Dry, mealy
FLOWER COLOR White
SPECIFIC GRAVITY High
RESISTANCES* Moderately resistant to scab, blackleg
SUSCEPTIBILITIES* Subject to second growth, knobbiness, hollow heart in Alberta. Susceptible to leaf roll, verticillium wilt, virus X and Y.
STORABILITY/DORMANCY Stores well, long dormancy.
COMMENTS More Russet Burbanks were grown in Alberta in 1985 than all other cultivars combined. It accounted for 5,062 ha or 52% of the total potato area. It is the main French fry cultivar grown in southern Alberta but is also a major fresh market potato used especially for baking. Russet Burbank is a late variety.
PARENTAGE/BREEDER Probably a mutant of Burbank, selected by D. Sweet in 1874. Neither bred nor selected by Luther Burbank as commonly reported.

NORCHIP

PRIMARY USE Chipping
MATURITY Mid-season
TUBER: **SHAPE** Round to oval
EYES Shallow
SKIN COLOR Creamy white
SKIN TEXTURE Smooth
FLESH COLOR White
FLESH TEXTURE Dry, mealy
FLOWER COLOR White
SPECIFIC GRAVITY High
RESISTANCES* Moderately resistant to scab, verticillium wilt, virus Y.
SUSCEPTIBILITIES* Black leg, leaf roll, virus X, growth cracks.
STORABILITY/DORMANCY Stores well, requires sprout inhibition for long-term storage.
COMMENTS Ranked second in area planted of all cultivars produced in Alberta in 1985. (1,422 ha or 15% of total potato area). Norchip is the main chipping potato in Alberta.
PARENTAGE/BREEDER A 1960 cross between two seedlings from North Dakota State University and University of Manitoba. Dr. Robert Johansen, North Dakota State University. Released 1968.

NORGOLD RUSSET

PRIMARY USE Fresh market only. Good boiling and baking.
MATURITY Early mid-season
TUBER: **SHAPE** Oval-oblong
EYES Shallow
SKIN COLOR Tan
SKIN TEXTURE Russeted, netted
FLESH COLOR White
FLESH TEXTURE Dry, mealy
FLOWER COLOR Pink
SPECIFIC GRAVITY Medium to high
RESISTANCES* High resistance to scab.

*See end of cultivators description.

SUSCEPTIBILITIES*
STORABILITY/DORMANCY Stores well. Medium dormancy (see comments)
COMMENTS Norgold Russet ranked fourth in area planted of all cultivars produced in Alberta in 1985. (730 ha or 6.5% of total potato area). Norgold Russet is an early market russet potato that tends to lose its strength in the market place by the time Russet Burbanks are in strong supply.
PARENTAGE/BREEDER Dr. Robert Johansen, North Dakota State University.

NORLAND

PRIMARY USE Fresh market only. Good boiling, fair baking.
MATURITY Early
TUBER: **SHAPE** Round to oval
EYES Shallow
SKIN COLOR Red
SKIN TEXTURE Smooth
FLESH COLOR White
FLESH TEXTURE Somewhat wet
FLOWER COLOR Purple
SPECIFIC GRAVITY Medium
RESISTANCES* Moderately resistant to scab, leaf roll, verticillium wilt, viruses X and Y.
SUSCEPTIBILITIES* Highly susceptible to silver scurf.
STORABILITY/DORMANCY Short dormancy. Red color tends to fade by the New Year.
COMMENTS Norland ranked third in area planted of all cultivars produced in Alberta in 1985. (1,057 ha or 11% of total potato area). Norlands are first reds on the fresh market, replacing imported Red Pontiacs by mid-August.
PARENTAGE/BREEDER Redkote crossed with NDSU seedling. Dr. Robert Johansen, North Dakota State University. Released 1957.

SUPERIOR

PRIMARY USE Chipping
SECONDARY USE Early fresh market
MATURITY Early mid-season
TUBER: **SHAPE** Oval
EYES Medium in depth
SKIN COLOR Creamy white
SKIN TEXTURE Smooth
FLESH COLOR White
FLESH TEXTURE Dry, mealy
FLOWER COLOR Pale lilac
SPECIFIC GRAVITY Medium
RESISTANCE* Moderately resistant to common scab.
SUSCEPTIBILITIES* Susceptible to verticillium wilt and potato virus.
STORABILITY/DORMANCY Not a storage potato.
COMMENTS Superior ranked fifth in area of all cultivars produced in Alberta in 1985 (478 ha or 5% of total potato area). It is grown primarily for chipping, however extra area is planted for early fresh market.
PARENTAGE/BREEDER A 1951 cross between two numbered seedlings by the University of Wisconsin. Released in 1961.

SHEPODY

PRIMARY USE French fry
SECONDARY USE Fresh market
MATURITY Mid-season
TUBER: **SHAPE** Oblong to long
EYES Shallow
SKIN COLOR Buff
SKIN TEXTURE Smooth to light net
FLESH COLOR White
FLESH TEXTURE Dry, mealy

FLOWER COLOR Light violet.
SPECIFIC GRAVITY High
RESISTANCES* Moderate resistance to Rhizoctonia
SUSCEPTIBILITIES* Susceptible to potato viruses S, X and Y, leaf roll. Moderately susceptible to common scab.
STORABILITY/DORMANCY Currently not stored for processing.
COMMENTS Shepody ranked sixth in area planted of all cultivars produced in Alberta in 1985 (430 ha or 4.5% of total potato area). Shepody's area increased dramatically in 1985 as growers and processors recognized it as a good, high yielding early French fry potato.
PARENTAGE/BREEDER A 1969 cross between Bake King and a Fredericton seedling. Agriculture Canada, Fredericton, New Brunswick. Released 1980.

SANGRE

PRIMARY USE Fresh Market
MATURITY Mid-season
TUBER: **SHAPE** Oval
EYES Shallow
SKIN COLOR Red
SKIN TEXTURE Slightly rough
FLESH COLOR White
FLESH TEXTURE Somewhat dry and mealy
FLOWER COLOR Lavender
SPECIFIC GRAVITY Medium
RESISTANCES* Moderately resistant to leaf roll, net necrosis, and rarely exhibits hollow heart, internal discoloration and blackspot.
SUSCEPTIBILITIES* Susceptible to verticillium, early and late blight.
STORABILITY/DORMANCY Holds bright red color well past Norland.
COMMENTS Sangre ranked seventh in area of all cultivars produced in Alberta in 1985 (147 ha or 1.5% of total potato area). Sangre is slow to emerge but grows rapidly. Sangre is later than Norland, however yields comparably and has the advantage of holding its bright red color throughout long-term storage.
PARENTAGE/BREEDER A 1967 cross between Viking and a numbered seedling from Aberdeen, Idaho. Selected at San Luis Valley Research Center, Colorado. Released 1981.

CARLTON

PRIMARY USE Fresh Market
MATURITY Early
TUBER: **SHAPE** Oval
EYES Shallow
SKIN COLOR Creamy White
SKIN TEXTURE Smooth
FLESH COLOR White
FLESH TEXTURE Somewhat wet
FLOWER COLOR Light purple with white tips
SPECIFIC GRAVITY Medium
RESISTANCES*
SUSCEPTIBILITIES* Susceptible to common scab.
STORABILITY/DORMANCY Early maturing and not considered a long-term storing potato.
COMMENTS Carlton ranked eighth in area planted of all cultivars produced in Alberta in 1985 (41 ha or 0.4% of total potato area). Carlton was selected to replace Warba, a high yielding but very rough first early potato.
PARENTAGE/BREEDER Selected in 1962 at Agriculture Canada Experimental Station at Scott, Saskatchewan, from a cross at Agriculture Canada Research Station, Fredericton, NB. Released 1979.

*Resistances and susceptibilities are generally listed as described by the breeder and may not be applicable under Alberta conditions.

PLANTING MANAGEMENT

Three general factors contribute to achieving a high stand of uniform plants that produce a profitable and quality potato crop. These are: seed lot condition and subsequent handling; cutting management to achieve optimum seed size with low portions of multi-cut pieces; planter management to ensure near perfect drops.

SEED SELECTION AND SEED STANDARDS

Seed Selection. Selection of seed stock of high quality is necessary for maximum yields of commercial potatoes. Characteristics of high quality seed are: trueness to cultivar, freedom from seed-borne diseases, physical soundness and an approved field inspection report. The seed should have been produced under suitable growing conditions and stored at temperatures of 3-5°C. Successful growers always use Foundation or Certified seed that is relatively free from disease. Bacterial and viral diseases that reduce the yield of potatoes may not produce visible symptoms on the outer surface of the tubers so appearance is not necessarily an indication of quality seed. A plant from an infected seed piece can serve as a source of infection for the spread of diseases to other plants in the field through insect vectors or mechanical contact. Good seed is a sound investment.

Seed Standards. Foundation or Certified seed is used to produce commercial potatoes in Canada. These classes must meet the standards set out under the regulations for seed potato certification administered by the Food Production and Inspection Branch of Agriculture Canada. Seed must meet certain size standards, but freedom from disease as determined by field inspection during the growing season is the most important standard. Before purchasing Certified or Foundation seed, the grower should examine the field inspection reports to determine the disease status of the seed stocks at the time of field inspection. Refer to the seed production section where a description of seed classes and their disease levels is presented.

SEED CUTTING

The importance of proper seed cutting cannot be over emphasized. The cut seed lot has a direct bearing on plant stand, vigor and yield. Unless producers do the best job possible of cutting they will not achieve the best crop possible. No amount of effort and inputs will make up for a poorly cut seed. It costs as much to produce a field of low yielding hills as it does a field of high yielding hills, so it is imperative that growers strive to plant the best seed pieces possible.

The object of cutting is to produce seed pieces uniform in size with an average weight of approximately 50 g and that have as few cut surfaces as possible. The seed lot to be cut should therefore be as uniform as possible ranging up to about 200 g in size. Large tubers weighing 300 g or

more produce pieces with many cut surfaces. Recent research in Alberta using seed pieces taken from commercial cutting operations has firmly established that growers should try to maximize the number of seed pieces with single cuts, and minimize the portion of two, three or four cut surfaces. It has been established that great hill to hill variability in yield is largely caused by seed pieces that vary in size and number of cut surfaces. Variation in seed piece weight is not as important as variation in the number of cut surfaces; however small pieces, less than 40 g are very unproductive. These small seed pieces emerge later, and produce potato plants of low vigor with only one or two mainstems. They may fail to produce any marketable tubers.

Whole seed does not necessarily produce significantly higher yields than single cut pieces and this fact offers an advantage to the grower. Typically a whole tuber that passes through a cutter without being sliced will weigh about 60-80 g, whereas single cut pieces will normally weigh about 50-60 g. The weight of seed required per field would therefore be less when a majority of pieces are single cut from 100-150 g seed tubers. In addition, the yield will not be significantly different, and the grower is not faced with the problem of a high tuber set resulting in a smaller tuber weight which is thought to be associated with whole-tuber seed.

Seed lots that vary in size are difficult to cut to a uniform size, and the resulting variation contributes to frequent planter errors such as doubles and misses.

A 1985 seed piece survey in Alberta found that slivers and other unplantable tuber waste accounted for up to 9.3% of the cut seed lot. This represents a severe waste for the potato grower for three reasons. First these pieces have been paid for at the going seed rate; and secondly, many of these pieces will end up in the planter where they may result in double drops. And thirdly, if planted singly, these chips or slivers will result in a miss or an unproductive plant.

Determining Seed Size. An average seed piece weight of 50 g is required to produce high yields provided the lot contains a high portion of single cuts. Upon starting each different seed lot growers should take a small pailful of cut potatoes weighing about 5 kg and check average weight and composition. The average weight can be calculated by taking exactly 5 kg and counting the pieces. (Table 2).

Table 2. Average weight of seed pieces in a 5 kg sample.

Number of pieces	Average Weight
125	40 g
100	50 g
83	60 g
71	70 g

Another way to calculate average weight is to exactly weight a sample and divide by the number of seed pieces. For example a 5.7 kg sample with 103 pieces has an average weight of 55 g. The lot can then be separated into whole pieces, single cuts, double cuts, center portions, double cut quarter portions, pieces with three cuts, four cuts (they do occur) and slivers. A producer then gets an idea of how the sample is composed.

A definite recommendation on the portion of the various pieces is not possible; however, for economy and performance a lot containing 20% whole seed (60 g average), 60% single cuts (50 g average), and 20% of the pieces with two or more cuts, would be considered very good. Realistically growers will usually find a higher proportion of two or more cuts, but should adjust the cutter to attain the highest portion of single cuts and the lowest portion of three cut pieces possible, and still maintain the minimum 50 g average. Tubers less than 80-90 g should be screened prior to reaching the cutters and left as whole seed pieces.

Whole Versus Cut Seed. Whole seed generally out-yields seed lots containing pieces with a wide range in the number of cut surfaces; however, research conducted throughout Alberta by the University of Alberta has shown that whole seed is not significantly better than single cut pieces, that is, tuber halves of similar size. But there are distinct advantages to using whole seed, especially for the seed grower. Uniform lots of small tubers ranging in size from 50 to 75 g will produce high vigor, high stem counts, high tuber set and a potentially high yield of uniform tubers that tend to be smaller owing to the heavy set.

Elimination of the cutting process reduces the spread of tuber-borne diseases which is an advantage to both seed and commercial growers. Commercial growers who normally space seed at 30 cm in the row, should extend this to about 35 cm to compensate for slightly increased tuber set if they plant whole seed or seed lots with more than 50% whole seed. This can be very important to French fry growers who strive to grow relatively large tubers for their processing company.

SEED PIECE REQUIREMENTS

The amount of seed required by the potato grower will depend on average seed weight between-row and in-row spacing. Typically rows are 90 cm apart and seed is placed from 15 cm to 40 cm distance in the row.

The closest in-row spacing is used by irrigated seed growers, and the farthest spacing is used by dryland commercial growers. The most common commercial spacing is 25-35 cm.

Table 3 lists the amount of seed required for different in-row spacings. The between-row spacing is set at 90 cm and growers with wider rows should *reduce* the requirement proportionately. Narrower between-row spacing will *increase* seed required.

Table 3. Weight of seed required for rows 90 cm apart using 40-70 g seed pieces spaced 15-40 cm apart in the row.

In-Row Spacing	Kilograms of seed per hectare			
	40 g	50 g	60 g	70 g
15 cm	2960	3700	–	–
20 cm	2220	2775	3330	–
25 cm	1775	2220	2665	3110
30 cm	1480	1850	2220	2590
35 cm	1270	1590	1900	2220
40 cm	–	1390	1665	1945

The two extremes in Table 3 have not been calculated because planting 60-70 g pieces at 15-20 cm spacings would result in both a high planting cost and produce an excessive number of small tubers. Small pieces averaging 40 g spaced at 40 cm in the row will result in reduced yield. To calculate rate per acre based on this chart multiply the rate in kg/ha by 0.9. For example, 1850 kg/ha (50 g pieces spaced at 30 cm) is the equivalent of 1665 lb/ac. Seed growers who plant 50 g pieces at 20 cm in-row spacing are planting 2775 kg/ha or 2500 lb/ac.

Seed Spacing. Normally seed pieces are spaced between 15 and 40 cm apart and this wide variation depends on many factors. The closer spacings are used for seed crops and irrigated potatoes, whereas the widest spacing would be used for fresh market dryland crops. Cultivar, fertility and length of season will also affect spacing. Table 4 lists usual spacings for the eight most planted cultivars. The table assumes optimum fertility, weed control and other cultural practices.

Table 4. Recommended spacing for potato cultivars in Alberta.

Cultivar	Spacing (cm) Production Method and Market				
	Irrigated Seed	Irrigated Fresh Market	Irrigated Process	Dryland Seed	Dryland Fresh Market
Russet Burbank	20-25	30	30	30	30-35
Norchip	15-20	–	25	–	–
Norgold Russet	15-20	25	–	25-30	30
Norland	15-20	25	–	25-30	30-35
Superior	20	25	25	25-30	30-35
Shepody	20-25	30	30	30	30-35
Sangre	20	25	–	25-30	30
Carlton	15-20	25	–	25-30	30

15 cm = 6", 20 cm = 8", 25 cm = 10", 30 cm = 12", 35 cm = 14"

PLANTING FOR BETTER STAND, YIELD AND QUALITY

High plant stands contribute to high yields of uniform potatoes. As discussed above, seed piece size and uniformity contribute to uniform hill-to-hill production. Fortunately uniform seed also contributes to high stands because of better planter performance.

Blanks in the field resulting from weak seed pieces or from planter misses result in reduced yields. Plants adjacent to a miss compensate partly by being more productive; however, the increased yield is not sufficient to compensate for the zero yield of the missing plant.

In the seed cutting section productivity of seed pieces was stressed. An unproductive seed piece costs as much to plant and grow as a higher yielding piece. Taking this argument further, production costs for a field with a poor stand are essentially the same. Ideally then, growers try to plant vigorous high yielding seed pieces and achieve near perfect plant stands at the same time.

Typical plant stands in Alberta range from about 75% to 95%. To determine plant stand calculate the distance required for 100 plants based on in-row spacing that was desired. For example, seed growers with a 20 cm in-row spacing should find 100 plants in 20 m of row (100 plants x 20 cm = 2,000 cm = 20 m). If they find only 85 plants in the 20 m row then they have a 85% stand. To correct a plant stand problem a grower must know why there are misses. Poor stands or loss of stand after emergence can result from several causes: planter misses, seed piece decay, cultivator removal, and plant death from blackleg or other diseases. Contamination of seed lots with sprout inhibitors must be avoided as even minor contact with CIPC vapors can cause delayed emergence, reduced vigor and stand reduction.

Fine management practices contribute to the establishment of good potato stands in addition to quality seed and proper cutting. They are: sanitation, handling and storage of seed, planter management and operation, soil conditions, and cultivation.

Sanitation, Handling and Storage. Seed lots should be stored, cut and handled under sanitary conditions to prevent spread of disease and reduce losses from rot organisms. The seed storage area should be cleaned and disinfected and dirt floors should be scraped to fresh soil. Walls, floors and all surfaces that will come in contact with the seed lot should be disinfected with bleach, quatenary ammonium or formaldehyde.

Potato pilers, cutters and planters should be cleaned with high pressure washers and subsequently disinfected.

Prior to cutting, seed should be warmed at about 15°C for 10 days unless sprouts have already appeared. This warming process helps break the dormancy that was maintained during cold storage. Seed should be planted immediately after cutting, or the seed should be stored in conditions that will cause the cut surfaces to heal or suberize, a process that seals the cut and reduces shrinkage and infection. Tubers will suberize when kept at about 15-20°C with high humidity and good air movement for about 5 days. If cut pieces are to be stored for several more days they should be then cooled down. As some of these temperature shifts are not practical with large seed quantities growers are best advised to cut just prior to planting or within a few days. Precautions should be taken at all times (during and after cutting and at planting time) to ensure the seed pieces are not exposed to drying conditions and direct sun.

Seed-piece treatments must be applied after cutting as insurance against adverse post-planting conditions to all seed lots. Be certain that the applicator is calibrated since these fungicides may reduce plant vigor if applied too heavily yet complete coverage of cut surfaces is necessary. Refer to the seed production section for fungicidal treatments. Well suberized seed is not normally treated; however if growers choose to treat, they should do so after cuts are healed.

Adherence to proper sanitation, storage and handling conditions as well as seed-piece treatments contributes to seed performance and lack of field blanks.

Planter Management. Establishing a high stand is critical if high yields of quality potatoes are desired. To this point we have stressed cutting management, seed handling and disease prevention all of which contribute to plant stand. Mechanical operation of the planter itself contributes significantly to plant stand. Planters should be maintained in good working order and run by competent people. This process is considered so important that at least one grower in Alberta plants his entire 75 ha seed operation with a two-row cup-type planter and family help. This is not practical for very large operations but the importance of good mechanical operation and good workers needs to be stressed.

Pick-type planters require constant monitoring and worn or damaged spikes must be replaced. The number and postion of picks on the picking arm can be adjusted to ensure that the proper number of seed pieces are dropped. Seed must be able to flow freely to the picker bowl and must not be knocked off before the picker arm opens.

Cup-type planters must be equipped with cups suited to the majority of seed pieces. Again the importance of a uniform seed lot must be stressed. Large whole seeds or long half slabs may fall out of the cups: small seed pieces may double up. As with pick planters these must be kept clean and adjusted to ensure proper flow and pickup of pieces. Planters should be calibrated for each seed lot by running seed out over a set distance and checking for accuracy of spacing and for misses.

Seed pieces are normally planted 12-15 cm below field level. Shallow planting can result in uneven emergence and contribute to some tuber greening and excessive depth can delay emergence and reduce vigor.

Seedbed Preparation. Personal preference and soil type will determine types of soil preparation methods. In any case soil should be worked deep - normally by fall plowing - and prepared into a smooth uniform but firm seedbed. Compaction and rocks will interfere with planting and hilling and may cause clod problems at harvest.

GENERAL CULTURAL PRACTICES

PLANNING FOR EARLY HARVEST

Early harvest can mean one of two things. The first is the traditional early harvest for the late July or early August market. The second is the timely harvest of the main potato crop before adverse weather sets in. In 1984 and 1985 many growers left potatoes in the ground or had many damaged because of unseasonably early cold weather.

In recent decades the potato harvest has often continued well into October; however, if the past two seasons are an indication that the fall season is shortening (there is no hard evidence of this) then growers may want to evaluate their growing management. Many growers would admit to pushing for maximum yields at the expense of quality. Harvesting a top quality crop yielding 35 t/ha (15 tons/ac) of which the majority is storable and marketable, likely makes more economic sense than harvesting 50 t/ha (22 ton/ac) if the quality is reduced and cullage is high. Recent experience has also shown that the late crops harvested in cold and freezing conditions present storage problems and a reduction in processing quality. No one can change the weather, but growers can follow a few procedures to help mature a quality crop a bit earlier. The following management practices are generally used by growers who are planning to market early and by those who want to have a timely harvest.

Fall Soil Preparation. Days can be added to the season only in the spring. Although in conflict with soil conservation practices, fall cultivation of fields to be planted to potatoes reduces the amount of spring work and possibly advances the planting date. As discussed in the soil management section there are methods to control erosion in fall-worked fields. Grain stubble can be plowed

or disked and spiked as preferred. Phosphorus and potassium can be applied in fall as it is very immobile and will not be lost. Deep shanked nitrogen may also be applied; however growers are reminded that nitrogen can be lost over winter. Irrigation in southern Alberta may be advisable if moisture reserves are low.

Planting. Soil temperatures should be at least 5°C before potatoes are planted. Although in unseasonably warm springs this can range from April 1 to 10 in the south and from April 15 to 25 in the north, some discretion is advised. Growers obviously place the crop at some risk if planted too early, even if soil temperatures are high enough. In 1985 early emerging fields were lightly frozen well into June, but as the plants had an early start and had well developed root systems they soon recovered.

Cultivar and seed selection are critical to early harvesting. The early market grower plants relatively early cultivars like Norland, Superior, Shepody and Norgold Russet. Russet Burbank accounts for over one-half of the potato area in Alberta - and it is late. Therefore other practices discussed here apply especially to this cultivar. Quality disease free seed cut as previously described contributes to a high stand of fast growing and vigorous plants.

Early planting usually means cool soil and possible seed decay. Seed piece treatments to reduce or prevent seed decay or seedling death are highly recommended. Seed lots should be prewarmed to break dormancy prior to cutting and planting. Sprouts should be swelling, but not elongating, at planting time. Control of weeds, insects and disease is necessary to keep the potatoes growing vigorously which will contribute to yield - a major concern of early marketers.

Fertility. Growers should follow the fertilizer recommendations in this guide, paying particular attention to nitrogen. Nitrogen in excess amounts can delay tuber set and maturity by up to 15 days.

Irrigation. Moisture levels of at least 60% of available capacity are required throughout the growing season. Contrary to popular belief potatoes do need adquate moisture in early stages of growth. Tuberization starts very early (when plants are as small as 20-25 cm) and adequate moisture at the pre-bloom stage can help increase tuber set and yield. (Refer to the Irrigation section).

CULTIVATION

Soil Compaction. The use of large equipment, including large trailers for hauling potatoes, can cause soil compaction. As cropping becomes more intense, especially under irrigation, compaction that can affect potatoes and other crops is likely to increase. There have been instances in the Vauxhall area where peas following potatoes were dwarfed and stunted in narrow bands. The affected plants were growing in highly compacted soil presumably from the harvesting or hauling equipment used for the potato crop the previous year.

Potatoes are quite sensitive to the physical condition of the soil because the more dense soil can interfere with root penetration and therefore planting growth. Generally, plant growth is slower and less vigorous and potato yields are reduced.

Compaction can result in hand pans, poor water and air penetration and clodiness, and may result in nutritional deficiency (especially phosphorus, delayed maturity, restricted root development and distorted tuber shape).

Fall plowing or subsorting should improve the structure of compacted soil caused by the operation of heavy tillage equipment and harvesting machinery.

Cultivation. Some cultivation of potatoes is required for weed control and for hilling; however excessive cultivation is not only unnecessary it may add to compaction below the working level.

Aeration of most soils used for potato production should not be necessary. Soils not recently disturbed give off more heat to the night air than a newly cultivated soil. The extra heat may reduce light frost damage following emergence. Cultivation after the application of pre-emergent herbicides tends to promote weed seed germination and may reduce the effectiveness of the chemical.

Hilling. Hilling is done for two main reasons. Because some tubers set on rhizomes that are near the soil surface they are subject to greening and frost damage. Unhilled rows may crack as tubers grow, or they may erode following irrigation leaving tubers exposed. Hilling also kills or buries weed seedlings.

In Alberta most growers use rolling-type cultivators for hilling; however some prefer the combination disc/shovel hiller. Hills should be high enough so that the highest tubers will be covered by 10 cm of soil. The furrows created should be fairly shallow as deep troughs tend to overheat, dry out, restrict root growth and actually damage roots if done too late in the season. Soil creating the hill should not bury more than a few of the new potato shoots. If done when the plants are above 15-20 cm excessive root damage can occur and diseases may be spread from plant to plant.

FIELD APPLICATION OF SPROUT INHIBITORS

One chemical, maleic hydrazide (MH), commonly available as Royal MH60SG (Uniroyal) is registered for field application to prevent sprouting in storage. There are many advantages to field applying a sprout inhibitor:

- it can be applied to very small plots of potatoes.
- potatoes are not subject to in-storage stress associated with heat-generated application of CIPC.

- storages of other potato lots designated for seed are not contaminated when they come in close contact with potatoes that have been field inhibited.
- non-certified potatoes that have been field treated cannot be later used for seed. (Some growers would consider this a disadvantage; however, producers are strongly urged to use only certified seed. Field treating prevents any change of plans during storage prior to in-storage treating).
- field treating reduces the number of volunteer potatoes the following spring.

The disadvantage of using maleic hydrazide is that it is an extra field operation and the crop must be closely monitored to ensure correct timing of application.

The manufacturer of Royal (MH60SG) is currently warning against use of this product on irrigated Russet Burbanks as there is some indication that stem end cracking and elephant hide may result. Double rate applications were made to test plots of irrigated Russet Burbanks in 1985 and no incidence of these disorders was observed. Growers of irrigated Russet Burbanks may wish to check with the manufacturer regarding current recommendations prior to using.

Directions for Use. Apply Royal MH60SG at 5.65 kg/ha (2.3 L/ac) in 300 L of water per hectare (120 L/ac) using ground equipment. MH60 can be applied by air with a minimum of 100 L/ha (40 L/ac).

Timing. Timing is important as the MH must be translocated to the tubers and therefore must be applied after tuber formation while vines are still green and active. Normally MH is applied 2-3 weeks past full bloom but at least 2 weeks prior to vine killing. Tubers should be 4-5 cm in diameter at time of application. Other formulations of maleic hydrazide may be available.

HARVEST MANAGEMENT

Potatoes are harvested from mid to late July until about mid-October in most years in Alberta. Early potatoes for chipping and fresh marketing are harvested when plants are immature; however about three-quarters of the potatoes grown in Alberta are harvested later in the season and put into storage. Typically early french fry crops are left a little later than early chippers because chip processors import fresh potato stocks for summer processing and are anxious to draw from Alberta-grown crops. (Fry processors can carry over frozen frys to bridge the supply gap between old and new crops. Chips have a more limited shelf life and the processed product cannot be stored between crops). The mid and late crops for chipping, frying and fresh market are taken off when the crop is more mature; however, even late potatoes are often immature because of irrigation, nitrogen applications, or a generally poor growing season.

Harvest date for early chip crops is largely determined by the yield and processing quality and contractual agreement; whereas, harvest of early fresh-market crops is largely determined by potential yield and market price. It is highly desirable to allow a potato crop to attain as much maturity as possible before harvest since more mature tubers usually have a higher specific gravity, have lower sugar levels, and are less subject to skinning and bruising. In Alberta, fresh market prices are often high in late July or early August and physical quality and shelf life may be sacrificed in order to create an early cash flow.

Potato vines are green and lush prior to early harvest and some form of vine killing is necessary. In Alberta potato tops are almost exclusively killed with the desiccant diquat.

VINE KILLING

Potato vines are chemically dried or mechanically removed for one or more of the following reasons:

- To remove vine growth that interferes with mechanical harvest.
- To artificially mature the tubers by causing the skin to set to reduce skinning, bruising and storage shrinkage.
- To terminate growth (and kill vines) for early market harvest.
- To terminate growth, control size and set skin for seed potatoes.
- To prevent spread of virus diseases by late aphid infections.

Both chemical and mechanical methods are used for vine killing. Diquat (Reglone) causes relatively slow vine death, while dinoseb (Topper) kills faster, and sulfuric acid (not currently registered) kills very quickly. Mechanical methods like rotobeaters or shredders terminate crop growth instantly. Vine killing with diquat is used by the majority of growers in Alberta and elsewhere, although about one-fifth of the Idaho growers use mechanical methods instead of chemicals.

There is a trend elsewhere towards a combination of mechanical and chemical killing. Rolling the vines prior to spraying has been shown to increase rate of vine kill up to 16%, especially in immature vines.

Allow a minimum of 10 days between top killing and harvest. Following are the chemicals registered for vine killing in Alberta:

Reglone (diquat) 2.5 to 4.25 L/ha in 550 to 1000 L/ha (0.62 to 29 L/ac in 225 to 450 L/ac). Use agral 90 at 1 L/1000 L of spray mixture.

Topper (dinoseb) 5.6 to 9.75 L/ha (2.3 to 3.9 L/ac) in 1000 to 1200 L/ha (400-500) of water.

Consult product labels for appropriate rates for the specific field conditions. Rates vary due to vine growth, maturity and rate of kill desired.

Effects of Vine Killing on Yield and Quality. The yield of potatoes is reduced by vine killing, and the earlier vines are killed the more the yield is reduced. Growers are faced with a choice between higher yields and earlier marketing. Contracts or agreements may specify a harvest date or have other clauses that dictate when the crop is ready; or the fresh-market price may be high and lower yields are offset by price, cash flow, and early position in the market place. In any case producers want to achieve the highest yield possible and still meet their market commitments. Vine killing too far in advance of harvest may reduce yield beyond an economically practical level and cause reduced quality. For many years it has been recommended that the registered chemicals be applied as a split application to cause a slow vine death, and therefore reduce the chance of stem end discoloration. However, research at Brooks and in Idaho shows that more rapid methods do not contribute to this disorder and therefore a split application should not normally be required. A single application of the registered products applied at least ten days before harvest is suitable under most conditions to kill vines. After ten days vines should be sufficiently dead to allow for an easy harvest, and the skin should be adequately set to reduce skinning and bruising.

Stem End Discoloration (SED). Stem end discoloration is a darkening of the vascular tissue and/or the cortex at the stem end of the tuber. In severe cases it may occur throughout the tuber. Speed of vine killing does not normally influence the amount of stem end discoloration; however, all methods of vine killing, including frost, may cause an increase in SED if the vines are immature or if the plants are under moisture stress. It is very important therefore, that growers use production methods that promote early growth and maturity. Nitrogen is required for adequate growth and yield, and may have to be applied during the growing season; however, excess nitrogen will delay tuber set and maturity by up to 15 days. Cultivar selection and planting date also influence maturity. As noted in other sections Russet Burbank is a late maturing cultivar and may not be suited to areas with a restricted growing season where yield and quality may be affected.

HARVEST TIMING

The decision to harvest is influenced by market, weather, labor, and total area to be harvested; but maturity of the crop should be the main determining factor. Maturity influences processing quality, ability to withstand skinning and bruising during harvest and handling, and affects storability and after-marketing shelf life.

Harvest conditions during the autumns of 1984 and 1985 stress the importance of planning a harvest schedule well before planting. Cultivar selection, planting dates, and crop management all affect the harvest schedule. Many large growers tend to manage production based on the assumption of a warm and open fall that will allow harvest well into October and perhaps November. However, recent experience has shown that if producers require 20 to 30 full days to complete harvest it cannot be left until all the area grown has reached full yield potential. Although relatively small amounts have been left in the ground owing to early freeze-ups in past years, many more have suffered frost and chilling injury. Process and fresh-market quality and storability have been severely affected in many cases and growers have suffered major financial losses. No amount of planning can substitute for a good growing season; however, planning does help reduce losses in years with adverse harvest weather. On the assumption that weather during harvest will be less than ideal, growers need to consider taking known yield losses by harvesting some fields early and planning to finish all of the potato harvest before severe frost can damage tubers.

After curing (14 days at 15°C and 90% humidity) potatoes must be cooled down to between 5-10°C for long-term storage. This presents a converse problem for the grower without refrigeration if the late fall weather is unusually warm at night. Long-term experience shows that more potatoes are lost because of cold than overheating in storages late in the fall. The influence of temperatures at harvest on mechanical damage and injury are discussed below.

HARVEST MACHINERY

There is a wide range of equipment available to potato growers. The majority of producers today have large areas in potato production and therefore use large two-row harvesters often in combination with windrowers so four rows are picked up by the harvester in one operation. However, a few smaller producers, especially market gardeners use one-row diggers.

Potato Diggers. One-row diggers can only be considered by small growers as they are slow and very labor intensive. One-row diggers lift potatoes out of the ground, separate them from the soil and then deposit the tubers back on the ground where they are later picked by hand into sacks of baskets for transport to a storage, grading, or selling area. Digger chains are usually driven from a power take-off so that the digger speed can be operated independently and can be adjusted to suit soil conditions.

In order to reduce potato injury with a digger a few simple procedures can be followed. The digger knife or blade must be deep enough to prevent cutting or scraping. If the level of the blade can be adjusted up or down relative to the digger chain then the top of the blade should be nearly level with the chain. This helps prevent tubers from riding up the blade and hitting the front of the chain. Ground speed should be between 25 and 40 metres per minute (1.5 to 2.5 km/h) and chain

speed should be slightly faster at about 35 to 45 mpm. Although the chain speed should be faster than ground speed, excessive speed can cause bruising. The chain must be agitated to remove soil; however, the soil should be travelling about two-thirds of the way up the digger before dropping through. Agitation can be reduced or increased by varying the number of eccentric sprockets.

Potato Harvesters. The increased area planted to potatoes by individual growers led to the development of large, high volume harvesters that can dig, partially grade and load potatoes in one operation. These harvesters are designed to: to recover as much of the crop as possible; cause the least damage possible; harvest rapidly; reduce labor; and remove soil clods and trash.

Mechanical harvesters used by most Alberta potato producers are two-row, pull-type or tractor mounted combines. Many growers also use a windrower ahead of the harvester. The windrower predigs two rows of potatoes and places them in proximity to two adjacent rows of undug potatoes. The four row lot is then harvested with the main combine. Windrowing allows the harvester (and hired labor) to make half as many trips down the field. It allows potatoes to be carried over the harvester chains in high volumes which can assist in the reduction of bruise.

There are many factors that complicate the separation of potatoes from vines, clods and stones. The maturity of vines or degree of vine kill, the size and shape of the potatoes, soil texture, and soil moisture all influence the harvest. Soils that are too dry cause lump and clod problems, whereas wet soils build up on chains and reduce soil separation.

REDUCING HARVEST DAMAGE

Four general areas influence the amount of bruising and mechanical damage at harvest: soil conditions; cultivar and tuber maturity; tuber temperature; and harvester condition and operation. Other sections have dealt with cultivar selection and maturity; however it is important to stress again the need to grow cultivars that will mature in a normal growing season. Nitrogen management and vine killing also influence tuber condition at harvest. Temperature and harvester operation are discussed here.

Temperature. Alberta's potato producers often do not have the luxury of picking and choosing their harvest dates. Late crops are frequently harvested from late September and throughout October so every harvest hour can count. Despite this pressure, growers should try not to harvest potatoes when the tuber temperatures are below 5°C. At these low temperatures the tubers are very brittle and subject to bruising and shattering.

To reduce the probability of not having to harvest in cold conditions growers need to plan their harvest prior to planting. Cultivar selection, planting date, fertility, irrigation, and vine killing all influence the harvest date. Year-in-year-out a grower who settles for a good yield and timely harvest is likely further ahead than one who continuously strives for maximum yield and often experiences problems caused by late harvest during cold weather.

Harvester Operation and Adjustment. The harvest operation typically accounts for the most of the mechanical damage received by potatoes. Other procedures which also cause damage are: unloading the haul track to the piler; piling; scooping and reloading to the truck; second truck unloading and subsequent handling during packaging or processing.

To help become aware of problem areas in the harvest operation it can be useful to follow potatoes through the harvester.

Growers and their hired labor must be familiar with both the machinery and field conditions. The harvester operator (if not the owner) must be aware of problem areas so he can make necessary adjustments or recommend changes to the farm owner or manager. Since operators cannot see the digging operation completely they must rely on the knowledge and experience of pickers and truck drivers to help. Therefore all harvest staff must know what to look for to ensure that as little damage as possible is done to the tubers.

Blade Height. The first potential bruise hazard encountered by potatoes is the blade and primary chain. As potatoes and soil are raised by the blade they must make a smooth transition onto the primary chain. If the rear of the blade is too low the tubers will hit the front of the chain. Growers should adjust the position of the blade so that the rear of the blade is nearly level with the front of the chain bed.

Chain and Link Coverings. Rubber coated chains are available that reduce tuber damage. All chains above the primary can be rubber coated. Chain links that face up or down should be covered with stiff belting or with wood boards to prevent tubers from coming in contact with them. Rubber coatings, belts and boards should all be checked frequently by the crew and operator. Belted chains are available that have no link ends to scrape and bruise potatoes.

Primary and Secondary Chains. Depending on soil type, the primary chain should be travelling at about ground speed. In heavier soils the speed should be slightly faster and in very sandy soils it can be slightly slower. The objective is to achieve a good soil loading on the lower end of the primary to prevent rolling and bounce. Most soil should have been removed by the top of the primary. Hydraulic shakers help agitate the chain better than common star shakers. Operators are reminded that star shakers will wear and break and must be inspected and replaced as necessary.

The drop to the secondary chain is a main source of bruising owing to the drop and presence of the deviner chain. Usually growers can lower the primary chain by 2-3 cm which will reduce the drop distance enough to lower bruise levels. Lowering the deviner chain reduces tuber bounce as tubers hit the chain and drop to the secondary. Many harvesters have a split secondary chain and tubers are damaged when they hit the inside links. These can be covered with a rigid piece of plastic, such as a one half portion of PVC pipe. The side links on the secondary chain should be covered with belting.

The secondary is driven by a large diameter drive that can be placed on the underside so that the drop distance to the rear-cross chain can be lowered. "Dog-legging" the secondary is a major job that should be attempted in winter.

A full width secondary is preferred over a split secondary chain. However staggered-length split secondaries are preferred to a pair with even ends. The outside chain of the staggered split pair travels farther to the back of the rear cross chain and the tubers are therefore placed uniformly on the rear cross.

Rear-Cross and Side Elevator. The rear cross should extend out over the lower end of the side elevator. This helps prevent tubers from being damaged on the frame between the two chains. The drop to the side elevator can also be lowered on some harvesters.

Speed and loading of the side elevator are critical. Typically the speed should be down to one-third to three-quarters of the ground speed depending on yield. Yields of less than 20 t/ha (8 tonnes/ac) will be carried up a side elevator travelling at about one-third of ground speed. As yields increase to 40-50 t/ha (16-20 tonnes/ac) the side elevator must travel at two-thirds ground speed (or more) to carry the load properly. Several bruising problems are caused by improper elevator speeds. Excessive speed causes bounce and rollback on the elevator, and it causes tubers to be thrown onto the roller table. A slow side elevator causes excessive piling and rollback; however, the majority of the side elevator problems are caused by excessive speed.

Rollback on the side elevator can be reduced with a hugger belt draped down on the elevator. However such a belt can increase rollback if the elevator flights are broken or missing. The most effective elevator consists of a flightless belt with a driven flighted hugger belt on top. This dual belt system carries tubers upward and gently drops them to the dirt eliminator. The flighted lower belt often "flings" the tubers from the elevator. The drop to the dirt table can also be reduced by "dog-legging" the side elevator; again a major job for the winter months.

Roller and Picking Table, and Boom. Rollers on the dirt eliminator should be rotating fast enough to help remove clods but tubers shouldn't be excessively spinning and bouncing. The transition from rollers to the picking table should be smooth.

Again the boom should be fully loaded like the side elevator, so that tubers help each other up. The speed of the boom should be slightly less than that of the side elevator. Typically this is about one-quarter to two-thirds of ground speed depending on yield. As with all other chains the rollers and chain ends must be covered with belting to protect tubers and all flights must be damage free.

Boom height is a problem for all growers. Maintaining a low drop without damaging previously loaded potatoes is difficult even with boom guards. An infra-red boom-height sensor can be installed for about four-thousand dollars. A sensor "feels" the infra-red radiation emitted by the tubers and automatically causes the boom height to remain constant over the pile.

TYPES OF HARVEST BRUISING

There are two major types of potato bruises caused at harvest. Whereas both are caused by the potato hitting or being hit by another object they occur under different conditions and for different reasons.

Blackspot bruises occur when the impact is hard enough to rupture individual cells below the skin without actually breaking the skin. After two days the damaged tissue will turn dark grey or black and can only be seen after the skin is peeled. Black spot bruises tend to occur near the stem end because of a slightly higher dry matter content.

Shatter bruises are thin cracks or splits in the tuber skin. They are more common on large tubers than on small ones. Because the flesh is open, diseases such as fusarium dry rot or bacterial soft rot can infest the tubers and cause breakdown. (Thumbnail cracks are a form of shatter bruise that commonly occurs when cold tubers are roughly handled out of storage and on packing lines).

Other general forms of bruises or mechanical damage include skinning, cutting and scraping. Skinned or scraped areas may turn dark as if scorched when exposed to drying conditions. All of these types of damage reduce the appearance of potatoes and often result in rot and decay.

Several factors influence the amount and severity of bruising. Soil clods that often result from working wet soils in spring can persist throughout the season, and can contribute to blackspot and skinning. Irrigation prior to harvest can soften clods and reduce damage. Other soil conditions that affect damage are nutrient levels and moisture. High nitrogen delays maturity and promotes skinning and blackspot. Dry soil also promotes blackspot but decreases the amount of shatter. However, shatter increases in wet soils and black spot decreases. The colder the potatoes the easier they bruise, but the amount of bruise is reduced if the tubers are somewhat dehydrated -

that is a bit short of water. Warm tubers are damaged less when water levels in the tubers are high.

BRUISE PREVENTION AT HARVEST

The following is a summary of recommendations that growers are advised to adhere to if they want to reduce harvest damage of potatoes.

1. Kill vines at least 10 days prior to harvest (for minimum bruising).
2. Overhaul and properly adjust all harvest equipment prior to harvest.
3. Make sure soil temperature is 5°C or preferably higher, before harvesting (compromise may be necessary late in season).
4. Make sure equipment operators understand the importance of keeping bruising at a minimum and how to properly adjust and operate the equipment to accomplish this.
5. Be sure that all chain or conveyor links and flights are properly padded, except the primary beds.
6. Use ample padding on deflectors, sharp points and any other place where bruising can possibly occur on harvesting equipment.
7. Adjust digger point (blade) deep enough so potatoes will not be bruised or cut and, at the same time, the proper amount of soil will be carried up the primary and secondary beds.
8. Maintain a proper forward speed-chain ratio to insure proper soil separation and, at the same time, keeping the conveyors as full of potatoes as possible. **This is important.**
9. Keep chain agitation at a minimum wherever possible. Give serious consideration to the installation of a hydrostatic agitation device on the primary beds to help control agitation more precisely.
10. Keep beds and conveyors sufficiently tight to avoid sagging and whipping.
11. Reduce drops to 15 cm or less including the loading boom. Consider installing deflector lip on end of boom to reduce bruising.
12. Check frequently for bruising at various points on harvesting and equipment.
13. Remove as many stones from fields as economically feasible.

SEED POTATO PRODUCTION

INTRODUCTION

The aim of seed growers is to produce the best possible seed. This means using every means at their disposal in controlling diseases, insects, and weeds, and using careful storage and handling techniques to ensure good health of the seed. Successful production of high quality "disease-free" seed potatoes requires sophisticated methods and strict disease control procedures.

Although the potato certification regulations list disease tolerances for the higher classes of seed, under no circumstances should growers feel satisfied with their seed quality if disease levels are just under the allowable tolerance. At all times they should strive to have their seed potatoes as free of diseases as is practically possible as this will enhance their reputation as a seed grower, increase the value of the crop and minimize potentially costly disease outbreaks.

SEED POTATO PRODUCTION CYCLE

In the Canadian potato certification scheme, there are six classes of seed potatoes: Pre-elite, Elite I, Elite II, Elite III, Foundation and Certified. Each class represents one generation; therefore, five years pass from the time Pre-elite seed is planted by an Elite seed grower until the commercial grower plants certified seed. The tolerances for disease increase slightly with each generation beyond Elite II.

In Alberta Pre-elite seed (disease free) is produced by Alberta Agriculture at Olds. Any seed grower who has five years of seed potato growing experience, who has received pre-Elite seed the previous year, or who has special permission from the Plant Health Division of Agriculture Canada and Alberta Agriculture, may purchase pre-Elite seed. Growers who do not meet the above requirements and wish to be seed growers must purchase Elite III or Foundation seed from other seed growers. There are many seed growers in Alberta who can supply seed of these classes. Prospective seed growers or commercial growers who want certified seed can get a seed source booklet from the Alberta Potato Commission office in Calgary.

The selection of cultivars is dependent upon available markets and grower preferences. The main cultivars grown in Alberta are Russet Burbank, Norland, Norchip and Norgold Russet. Demand for other cultivars is limited, therefore, these should be grown on a limited scale or for specialty markets.

Disease Freeing. Many methods are used to determine disease levels of seed potatoes. Test plants (plants that react in a specific way to infection with a pathogen) can be used to check for diseases. *Gomphrena globosa* is used to detect potato virus X; Rutgers tomato is used to detect potato spindle tuber viroid; *Chenopodium quinoa* is used to detect potato virus S; and Nicotiana glutinosa is used to detect potato viruses X, S and Y. Serological methods such as latex agglutination, slide agglutination, and ELISA (Enzyme-Linked Immuno-Sorbent Assay) are used to detect a number of the virus diseases. Culturing and staining methods are used to detect bacterial and fungal diseases. The PAGE (Polyacrylamide Gel Electrophoresis) test, and Dot Blot test, are used to detect potato spindle tuber viroid (PSTV).

At the pre-Elite stage, plants that test positive for any one of these diseases are discarded.

Once disease-free plants are produced, they are further increased in the greenhouse by meristem culturing or rooted cutting techniques. In Alberta, the initial increase is by meristem culturing. If necessary, the meristem cultured plants are further increased by rooted cuttings.

Propagation of seed potatoes by rooted stem cutting or meristem culturing is a rapid and easy way to multiply seed potatoes that are free of diseases such as bacterial ring rot, blackleg, common scab, phoma, verticillium wilt and fusarium wilt. Cuttings and meristem plants are planted in a greenhouse and the tubers are harvested. These tubers are further increased one generation in the field to produce pre-Elite seed that is sold to seed potato growers in Alberta.

Some diseases can be controlled by clonal selection as was practised in Alberta in the 1960's; however, many diseases (PSTV, PVX, PVS, blackleg and latent bacterial ring rot) cannot be controlled by clonal selection. As a result, most programs in Canada introduced the use of heat-treatment and meristem culturing supplemented with extensive testing to eliminate these diseases. These procedures are necessary to produce seed that is free of all known diseases. Even with these advanced techniques, growers must continue a system of sanitation and positive selection by thoroughly cleaning equipment and storages, removing diseased plants and only keeping healthy plants. Diseases such as potato virus X (PVX), potato virus S (PVS), potato spindle tuber viroid (PSTV), blackleg, bacterial ring rot (BRR), fusarium wilt, verticillium wilt and potato leaf roll virus (PLRV) can in some cases within one to two years re-infect seed potato stocks. To slow down this re-infection process, Elite seed stocks must be grown under strict sanitary conditions. Growers must be concerned about irrigation waters as a source of blackleg bacteria or fusarium and verticillium spores.

SANITATION

All seed growers must be extremely aware of and apply sanitation procedures. Sanitation consists of cleaning and disinfecting all equipment, storages, tools and pallet boxes that come in contact with the potatoes. Since most disinfectants are inactivated by soil and plant debris, it is essential that this material be removed from the equipment, by thoroughly cleaning with a hot water or steam cleaner. Then they should be thoroughly soaked with a disinfectant such as: bleach (sodium hypochlorite 10%); quaternary ammonium 0.08% (Hy-X, Roccal, but not Roccal II); formaldehyde 2-5%.

Without adequate sanitation, diseases such as bacterial ring rot and blackleg can infect seed stocks from contaminated equipment or storages.

Sanitation also includes disposal of cull potatoes, roguing and removal of diseased plants from the field. Cull potatoes should be removed from the farm as soon as possible and fed to cattle or buried in a land fill site.

When roguing, diseased plants must be removed from the field and disposed of. If left in the field, they can become the source of further spread of the disease.

PREPARATION OF SEED

Many seed growers grow their own seed, but some purchase Elite II, Elite III or Foundation seed from other growers. The first consideration when purchasing seed is quality. Buying from a grower with a good reputation will reduce the risk and increase chances of obtaining good seed. Growers purchasing seed from outside Canada should check with the Agriculture Canada officer-in-charge of Seed Potato Certification (Food Production and Inspection Branch, 9820 - 107 Street, Edmonton, Alberta T5K 1G2, phone 420-2800) before buying, as some U.S.A. seed potatoes cannot be recertified in Canada.

Seed potatoes, whether purchased or produced by the seed grower, should be warmed to 10-15°C for two weeks prior to handling. During grading and transporting, seed potatoes should not to be bruised or stessed in any manner. All rots should be removed prior to cutting. Cut seed should be treated with a fungicide and planted within a few hours of cutting. If not planted immediately, the seed-pieces should be suberized as outlined below for precut seed.

Cutters must be kept clean, sharp and disinfested. Seed cuttters must be adjusted to produce uniform seed pieces. Sharp knives result in clean cut seed-pieces that suberize quickly preventing decay.

Precut Seed. Seed potatoes can be precut up to 4 weeks prior to planting provided they are treated properly. Precutting seed allows the producers a little more flexibility at planting time. Potatoes that are to be precut should be warmed to 10-15°C and 95% relative humidity prior to cutting and maintained at 15°C for 2-4 days after cutting to promote healing of cut surfaces. If the potatoes are to be kept longer they are then cooled to 4°C for the duration of storage and again warmed prior to planting. Seed-piece treatments should not be necessary after suberization; however should be applied just prior to planting pre-cut seed.

Seed-piece Treatments. Fungicidal treatments that prevent seed-piece decay and fungal seedling disease are recommended particularly if seed-pieces are planted in cool wet soil or if a cool wet spring is anticipated. A number of fungi can decay the seed-piece wholly or partly, resulting in missing or weakened plants. The following fungicides are registered for use as seed-piece treatments:

Polyram WP (metiram 7%) at 1.5 kg/100 kg of seed potatoes

Dithane M-45, Manzate 200 WP, (mancozeb) at 0.5 kg/100 kg seed potatoes

Easout (thiophanate methyl) at 0.5 kg/100 kg of seed potatoes.

PLANTING

Higher classes of seed (that is, early generations) should be planted first so they can be top-killed and harvested early to prevent or limit entry of virus carrying aphids. Cup-type planters reduce the risk of disease spread and therefore are better than pick-type planters for planting seed potatoes.

Tuber Unit Planting. Tuber unit planting is a process where all seed pieces from a single tuber are planted consecutively in a row and are separated from seed pieces of another tuber. This method is used to identify tuber-borne diseases, separate them from current season infections, and make roguing easier. (All plants originating from an infested tuber are usually infected; however when diseases are introduced in the current season only one or two plants are infected).

The federal seed certification regulations require that Elite I and II seed potatoes must be produced from identifiable tuber units and that 100% of the crop must be planted with pre-Elite and Elite I seed potatoes, respectively. Elite III seed potatoes must have 10% of the crop planted in identifiable tuber units.

When cutting seed tubers, the knife must be dipped into a disinfectant such as 10% bleach or a quaternary ammonium solution after each tuber is cut. Examples of hand cut seed-pieces from tubers of various sizes are shown in Figure 5.

As tubers are cut, the seed pieces are dropped consecutively 15-40 cm apart in an open furrow. All pieces from one tuber are then followed by a double space as shown in Figure 6.

When a double space is left between tuber units, tubers in the outside hills often grow too large and rough, therefore, tuber unit planting without a space is acceptable for certification provided that when no space is left extra plants on each side of the diseased plant are rogued. For larger areas, where manual cutting and planting is not practical, whole tubers can be planted using cup-type or tuber unit planters. A tuber unit planter is a manually fed planter that allows tuber units to be planted consecutively with or without the extra space.

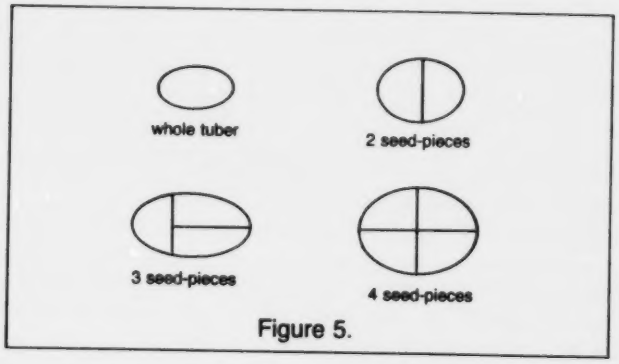


Figure 5.

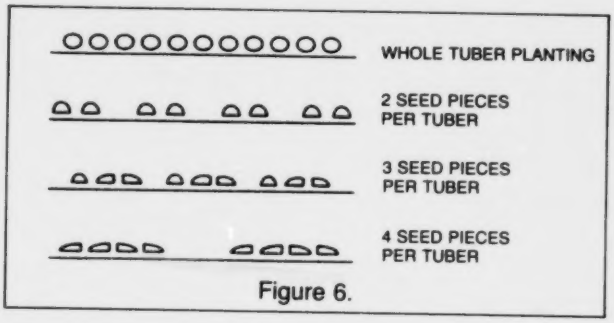


Figure 6.

FERTILITY

Seed potatoes require similar soil fertility to commercial potatoes except that it is necessary to provide all the nitrogen in the spring as later applications will delay tuber set or result in tubers that are generally too large for seed. Total nitrogen levels to a depth of 60 cm should be about 200 kg/ha (175 lb/ac) and phosphorus levels 110 kg/ha (100 lb/ac). Growers may wish to reduce nitrogen levels slightly as high levels of nitrogen produce immature tubers that bruise easily and store poorly. Although most Alberta soils are not deficient in potash some grower experience and research has indicated that when levels are below 400 kg/ha (350 lb/ac) potassium should be applied. Research in the U.S.A. has shown that potassium may increase disease and bruise resistance.

MAINTENANCE OF SEED POTATO FIELDS

Diseases in seed potatoes must be controlled. The presence of seed borne diseases may require that fields have to be rogued in order to keep the level of disease below the tolerances for that seed class. Reputations of seed growers depend upon the quality of the seed, and although at times it is not practical, they should strive for 100% disease freedom in all classes of seed potatoes. (Refer to the disease control section).

Insecticides are used to control insect vectors such as aphids and leafhoppers. Growers who are in high risk areas should use a soil applied insecticide such as Temik, Thimet or Di-syston. During the growing season, if aphids start increasing in a seed field, a foliar applied insecticide should be used. See insect control recommendations.

Weeds must be controlled in seed potato fields to allow for proper inspection and roguing. See weed control section.

Irrigation and Disease Spread. Irrigation water can spread some diseases, such as blackleg and wilts. Wheel-type and pivot-type sprinkler systems may spread blackleg, potato virus S, potato virus X and potato spindle tuber viroid. Precautions like disinfesting wheels should be taken when moving equipment from field to field or from plot to plot to prevent the spread of these diseases.

Roguing. Roguing is a means of removing diseased plants from within a field. All diseased plants including the

new tubers and seed-pieces should be removed early. Rogued plants and plant parts must be removed from within the field. After handling diseased plants, avoid handling healthy plants and disinfest hand and tools as soon as possible. Fields should be inspected for disease on a regular basis.

HARVEST MANAGEMENT

The performance of disease-free seed potatoes is often directly related to the physical health of the tuber. Healthy, sound tubers will perform better than bruised or damaged tubers even though the tubers have been cured properly. Whenever seed growers can reduce bruising and damage they improve the tuber performance. Factors such as harvesting in cool weather, fast chain speeds, high drops, and lumpy soil may result in tuber damage. If some bruising has occurred a post-harvest treatment with Mertect will help protect the tubers from storage decay.

Prior to any operation all equipment and tools must be cleaned and disinfested. Chains and conveyors should be maintained, repaired and adjusted properly to prevent bruising and scraping. Potatoes should not be dropped more than 15 cm in any harvest or piling operation, otherwise they can become bruised and this will affect their storability and subsequent growth.

Top-killing of potato vines allows for better tuber maturity and easier harvesting. A mature tuber has better skin set and is less effected by normal harvesting procedures. Diquat (Reglone) and dinoseb (Topper) are used for this purpose.

Seed potatoes should be top-killed as soon as sufficient size is obtained. Pre-Elite, Elite I and Elite II should be top-killed by August 1 and all other classes by August 20. All vines and leaves must be completely dead within 10-15 days of vine killing to prevent late season spread of leaf roll.

Fields are normally harvested two to three weeks after top-killing. A longer period in the ground after top-killing is undesirable as it may increase the incidence of Rhizoctonia in the harvested seed.

STORAGE MANAGEMENT

Each class and variety of seed must be stored separately to prevent mixing. Do not use sprout inhibitors in seed potato fields or in storages that are to be used for seed potatoes. Commercial potatoes that have been sprout inhibited in another storage with CIPC should not be stored later in a bin to be used for seed storage.

Thoroughly clean and disinfest storage facilities and all grading and handling equipment after planting is completed and again prior to harvest. Cure potatoes at 13-16°C and a relative humidity of 90-95% for 8-15 days to heal wounds and bruises. If the potato lot has been subjected to freezing conditions in the field, as many frozen tubers as possible should be removed prior to storing. The lot must be checked frequently after going into storage and regraded if frost damage (softening) later occurs. Seed potatoes should be stored at a temperature of 3-5°C with a relative humidity of 90-95% for long term storage. Only allow authorized personnel into the storage area and only after their footwear has been suitably disinfested.

GRADING

Remove all culls from the seed farm as soon as practically possible. Alberta seed growers normally sell their seed in bulk which must be graded to standards unless the buyer specifies otherwise. Most buyers prefer tubers ranging in size from 50 to 300 g, although the seed regulations allow a range in tuber size of 40-450 g in these bulk shipments. Both seed sellers and buyers are reminded that bulk seed lots with a wide range of sizes result in highly variable seed pieces which cause great hill-to-hill variations. A 300 g tuber will likely be cut into six seed pieces averaging 50 g. At least two (and possibly four) of these pieces will have three cut surfaces which result in low yielding hills. The new seed potato certification regulations use a size measurement rather than weight. Growers may get a copy of the new regulations from the Food Production and Inspection Branch in Edmonton. Both seed sellers and seed buyers are reminded that the buyer can ask for seed either by seed size or by seed weight.

When commercial growers pick up seed potatoes at a seed farm, it is mandatory that trucks be disinfested prior to loading their seed potatoes. This should be done away from the seed farm especially if the truck has hauled other potatoes.

MARKETING

Marketing of seed potatoes is the responsibility of the individual seed grower although Edmonton Potato Growers Ltd. does market for its member growers and some additional growers under a special agreement. The Alberta Potato Commission, Alberta Agriculture and the Seed Potato Growers Association cooperate in promoting the sale of seed potatoes to export markets, particularly in Washington, Oregon, and California. Growers selling independently should contact the Alberta Potato Commission for information, advice and contacts.

New seed potato growers need to consider both where and how they will market their seed. This information will assist them in deciding on quantities and cultivars to be grown.

SEED SELECTION BY COMMERCIAL GROWERS

Alberta seed potato growers have developed the reputation of producing some of the best seed potatoes in North America. The combination of favorable climate and grower ability and attitude have helped the seed industry expand significantly. Current seed production cannot keep up with the increasing demand.

Alberta and Canadian regulations have a zero tolerance for bacterial ring rot. Should ring rot be found in only one of several fields belonging to a seed farm, none of the fields will be certified. In recent years bacterial ring rot has been eliminated from seed fields.

Many of Alberta's seed potato growers' fields are also free of the latent viruses X, potato virus X (PVX) and potato virus S (PVS). Potato spindle tuber viroid (PSTV) and potato virus Y (PVY) rarely occur in Alberta.

In spite of these strict regulations and high standards of performance commercial growers must be selective of their source. Commercial growers should consider not only the seed grower's past performance but should check the field readings before buying seed. Seed should be inspected upon delivery and if commercial growers have concerns they should contact both the seed grower and the Food Production and Inspection Branch of Agriculture Canada immediately and request an inspection. (9820 - 107 Street, Edmonton, Alberta T5K 1G2, phone 420-2800).

SUMMARY OF SEED POTATO CERTIFICATION REGULATIONS

Application for Crop Inspection. Applications must be made on forms supplied by Agriculture Canada and received in the Food Production and Inspection Branch, Edmonton by June 30 of the crop year. It is important that this deadline be met so inspections may be scheduled. When the potatoes to be planted were purchased from another seed grower, the application must be accompanied by a tag or a copy of the bulk certificate from each lot of seed planted. (The remainder of the tags from bagged seed must be kept as they will be required at the time of the first inspection).

A map of the exact location of each lot must accompany the application.

Conditions to be met for Crop Inspection. The person or agency applying for inspection of a crop to produce pre-Elite, Elite I, Elite II, or Elite III must have successfully grown seed potatoes for five consecutive years and/or be approved by the officer in charge of seed potato certification. New seed growers will only be accepted where the inspector has verified adequate control measures to prevent bacterial ring rot before the arrival of new seed. Approval for planting of pre-Elite material will be made by the officer-in-charge in co-operation with the manager of the Alberta Seed Potato Program.

Seed potatoes must be of a Canadian Certified class (pre-Elite, Elite I, Elite II, Elite III or Foundation). Seed may also be imported for recertification from those states of the U.S.A. not prohibited under the quarantine regulations, provided certain criteria are met.

Written proof from the state certifying agency must be supplied stating that:

- The farm, all lands and buildings have been free from bacterial ring rot for at least five years.
- Field and cellar inspections show no PSTV in the crop.
- Winter tests show no PSTV in the crop.
- The number of generations the seed is removed from the disease free clonal selection or nuclear stock will be consistent with the Canadian seed class requirements.

In addition, a 400 tuber representative sample will be required for bacterial ring rot (BRR) testing. Should the test read positive for BRR and the seed lot already planted, the whole operation would be considered contaminated and no inspection would be performed on the farm.

All equipment used to plant, cultivate or harvest the crop must be thoroughly disinfested and free from pathogens. Crop inspection or a growing crop certificate may be refused if the inspector suspects that equipment used might be contaminated and would adversly affect the crop. Any community equipment used must be disinfested to the safisfaction of the inspector.

Different varieties of seed and different classes of the same variety must be separated by a minimum of two rows. The crop must be planted and cultivated such that a visible assessment of condition may be made.

Crops of less than ½ hectare (1 acre or less) of pre-Elite, Elite I and Elite II seed must be grown in identifiable tuber units. Elite III seed must have a minimum of 10% planted as tuber units. No crop inspection will be made where:

- Seed is growing on a farm where potatoes infested with BRR were produced or found in the previous year (or until the farm is no longer considered to be affected.)
- The crop is growing on a farm where commercial potato stock (non-certifiable) is planted.
- The crop is planted in a field where non-certified or BRR infected potatoes were grown in the previous two years. Any field in which there has been an occurrence of BRR must be kept free from any potatoes including volunteers for a full two years.
- The crop is located within 60 metres of other potatoes which show viral disease levels exceeding those allowed for Certified grade.
- The crop has been treated with or exposed to a sprout inhibitor.

Subject to the above, the growing crop will be inspected two or three times (depending on the class) by an Agriculture Canada inspector. A growing crop certificate will be issued for all crops that meet requirements. However, it will not be issued when the crop, or another crop derived from the same parent stock, is suspected to be contaminated with bacterial ring rot. BRR found at any time in the inspection process will disqualify all growers' seed from certification. PSTV found at any time will disqualify only the lot of seed in which it is found.

Tuber Inspections and Storage. Inspections will be made to determine adequacy of storage facilities and procedures. Each variety and class of seed potatoes must be stored in such a manner as to prevent any mixtures. Non-certified potatoes must be kept completely separate from certified classes. At shipping, tubers must be graded to standards before tags or bulk certification will be issued.

TUBER STANDARDS FOR CERTIFIED SEED POTATOES

Following are the grade standards for seed potato tubers.

Disease or Defect	Percentage by count
1. Soft rot or wet breakdown	0.1
2. Dry rot, including late blight	1.0
3. Scab and Rhizoctonia	
(a) slight severity	10.0
(b) moderate severity	5.0
4. Stem-end discoloration due to top-killing, frost, heat or drought with penetration from 6 millimetres to 13 millimetres.	4.0

The number of tubers showing visible symptoms of disease including leaf roll and verticillium wilt necrosis, or a varietal mix should not exceed the standards for that particular class of seed potatoes. All tubers must be firm, well shaped and free from external damage (2% tolerance). Tubers may range in size from 30-450 g (1 to 16 oz); however it must be repeated that a seed lot falling in this wide range is highly variable, difficult to cut and produces a poor cut-seed lot.

Reinspections of any lot of certified seed potatoes will be made at the buyer's request if it is submitted within two working days of receipt of the lot.

DISEASE STANDARDS FOR CERTIFIED SEED POTATOES

Elite I and Elite II must be inspected three times while growing and on the third inspection must be be free from visible symptoms of disease.

Following are the maximum percentages of diseased plants allowed in a growing crop planted to produce the various class of seed at the time of field inspection (Table 5).

Table 5. Disease Tolerances for Seed Potatoes

Disease	First Inspection	Second Inspection	Third Inspection
Elite III Class (Planted in tuber units)			
1. Bacterial ring rot	Nil	Nil	Nil
2. Potato spindle tuber	Nil	Nil	Nil
3. Blackleg	0.25	0.1	0.1
4. Wilts	0.25	0.1	0.1
5. Total, all viruses	0.25	0.1	0.1
6. Total, blackleg, wilts, viruses	0.5	0.5	0.25
7. Varietal mixture	0.25	Nil	Nil
Elite III Grade (Mass Planted Portion)			
1. Bacterial ring rot	Nil	Nil	Nil
2. Potato spindle tuber	Nil	Nil	Nil
3. Total, all viruses	0.25	0.1	0.1
4. Total, blackleg, wilts, viruses	0.5	0.5	0.25
5. Varietal mixture	0.1	Nil	Nil
Foundation Class			
1. Bacterial ring rot	Nil	Nil	Nil
2. Potato spindle tuber	Nil	Nil	Nil
3. Total, all viruses	0.25	0.1	0.1
4. Total, blackleg, wilts, viruses	0.5	0.25	0.25
5. Varietal mixture	0.1	Nil	Nil
Certified Class			
1. Bacterial ring rot	Nil	Nil	
2. Potato spindle tuber	Nil	Nil	
3. Any one virus	1.0	0.5	
4. Total, all viruses	2.0	1.0	
5. Total, blackleg, wilts, viruses	3.0	2.0	
6. Varietal mixture	1.0	0.1	

SOIL MANAGEMENT, FERTILITY & IRRIGATION

SOIL MANAGEMENT

Important aspects of soils that should be considered for potato production are texture, salinity, drainage, pH, organic matter content, erodability and fertility.

SOIL TEXTURE AND DRAINAGE

Texture describes the proportion of clay, silt and sand particles which make up a soil. Clay particles are very small, silt particles medium sized, and sand particles the largest.

The soil test identifies five texture classes for mineral soils:

1. very coarse (sand, loamy sand)
2. coarse (sandy loam)
3. medium (loam, clay loam, sandy clay loam and sandy clay)
4. fine (silt loam, silty clay loam)
5. very fine (clay, heavy clay)

A sixth group, organic soils, have no 'texture' as such since they contain very little or no mineral particles. Organic soils are not usually used for potato production in Alberta, but can be productive soils and interested producers should contact Alberta Agriculture for more information.

Generally, deep, well-drained, coarse textured soils such as loamy sands, sandy loams and loams are the best soils for potato production. A coarse textured soil has good drainage which reduces the possibility of disease problems and allows the soil to drain prior to harvesting.

A soil which contains a large amount of clay (a fine textured soil) becomes sticky when wet and lumpy when dry. If such a soil is dry at harvest, it is difficult to separate the potatoes from the soil lumps. Tubers harvested from a clay soil will also require considerable washing to remove soil particles.

Poorly drained soils can delay field operations and promote disease. Potatoes grown in such soils will have large lenticels (pores) and will not be attractive when marketed. Growers wishing information on drainage problems should consult their irrigation specialist or contact their nearest district agriculturist office.

SOIL SALINITY

Soil salinity, often referred to as alkali, is a problem in many parts of Alberta. Soil salinity is measured by electrical conductivity in millisiemens/cm. A reading of less than 4 is preferred for potatoes. Saline soils are often formed in areas where there is an excess of water which rises to the surface and evaporates leaving salts accumulated at the soil surface. Saline soils often develop near irrigation canals and may also be caused by the use of irrigation water which has a high salt content. These soils crust easily and are difficult to till if they are too wet or dry. Lumps may form on saline soils making harvesting of potatoes difficult.

Saline areas are usually moist but plants may suffer from a lack of water because they are unable to withdraw it from the soil. In these areas it is preferable to grow crops which have some salt tolerance such as barley, some forages and sugarbeets (when available). Potatoes grown on moderately saline soil will have reduced growth and the leaves will be darker and may be burned on the edges. In severely saline areas potatoes will not grow at all, and the bare area will be white or contain salt tolerant weeds such as, kochia, wild barley, or Russian thistle.

Saline areas can be improved by subsurface drainage. For assistance with drainage design or evaluation of salinity, growers should consult with an Alberta Agriculture Irrigation Specialist. (Refer to back cover.)

SOIL pH

Most Alberta soils have a pH in the range of 5 to 8 which is suitable for potato production. Some acid soils in central or northern Alberta may have surface or subsurface layers which are below pH 5. Surface layers can be improved by liming; however, if the soil at a depth from 15 to 60 cm is acidic, it is preferable to grow an acid tolerant crop such as timothy. High pH, or alkaline soils, occur when lime layers are near the surface in eroded or saline soils and may have reduced availability of phosphorus and other nutrients. Potato scab, a fungal disease, is more prevalent on soils with a pH from 5.2 to 6.8 than on soils which are more acidic or alkaline.

SOIL ORGANIC MATTER

Soil organic matter consists of plant tissues and animal wastes in various stages of decomposition. It serves two important functions in crop production. First, it behaves as a revolving nutrient bank account, and second as an agent to improve soil structure, maintain tilth, and minimize erosion.

Organic matter does not add any "new" plant nutrients but releases food in a form available to plants through the process of decomposition. Maintenance of organic matter is needed to sustain the long term productivity of the soil. In order to maintain organic matter the rate of addition of crop residues and manure must equal the rate of decomposition. Continuous production of row crops usually results in a rapid decline of soil organic matter. Bare soil between rows is similar to summerfallow and the total amount of residue added is small. Organic matter is maintained with rotations that include perennial forage crops, or by production of cereal crops where residues are not removed and minimum tillage is practised.

Manure is a valuable source of organic matter and plant nutrients. Manure may be applied in the fall at rates of up

to 100 t/ha (40 t/ac) every 3 to 4 years. Rates will vary depending on type, age and method of storage. As high rates of some manures may contain excessive amounts of salts that could injure plants, growers are advised to have a manure sample analysed or appraised at a soil laboratory. Excessive amounts of nitrogen may delay maturity. Manure containing straw from a grain crop that was treated with the herbicide picloram (Tordon) may cause abnormal growth of potatoes and other sensitive broadleaf crops, such as beans.

SOIL EROSION

A serious problem of soil loss by wind erosion can occur in Alberta as a result of the combination of climate, soil, and management practices in potato production. First of all, most of the potato production in Alberta is in the southern part of the province where winds, particularly the chinook winds of winter, often melt snow and leave fields bare and subject to erosion. Secondly, potatoes are usually grown on sand or sandy loam soils which are subject to erosion by the winds. Thirdly, tillage and harvest practices of potato production leave fields bare many months of the year. Fields are often plowed in the fall to incorporate straw or stubble and to prepare a seedbed for spring potato planting. Residues left after potato harvest do not afford protection from wind erosion. The result is that for a single crop of potatoes the soil is usually in an unprotected state the winter prior to planting and the winter after harvest. The combination of wind, soil type and management practices can produce severe and repeated wind erosion.

Soil formation is a natural and ongoing process, but if wind erosion is visible, soil losses are greater than rates of formation. One storm that removes a 7 mm layer of soil results in the loss of 100 tonnes of top soil per hectare (40 t/ac) and will require at least 10 years to be replenished assuming no further erosion occurs. Maintaining high yields of potatoes will become increasingly more dependent on the intensive use of fertilizers if erosion continues at its current rate.

The Soil Conservation Act passed by the Alberta Legislative Assembly in 1962, and revised in 1980, provides for a fine if a producer fails to comply with an erosion control notice issued by a soil conservation officer. More importantly, measures to stop or prevent soil erosion can be undertaken by a county or other government agency at the expense of the landowner. The landowner is also responsible for problems caused by drifting soil that fills irrigation or road ditches.

There are many options a producer can consider to control or limit wind erosion. The following are just a few.

- Delay cultivation of cereal stubble until spring.
- Seed oats, winter wheat, fall rye or barley in August after harvest of early potatoes; or aerial seed into a companion crop of late potatoes in August.
- Winter wheat seeded at a low rate can be planted as a companion crop in an established potato field and allowed to volunteer.
- Plant potatoes in rows at right angles to the prevailing winds to reduce drifting in the spring.
- Cultivate blowing fields with a row of lister shovels spaced about 1 metre apart on the back of a heavy duty cultivator. Ripping can be done to break up lumps on some soils.
- Rows of ditches at right angles to the wind will serve to trap drifting soil and act as a wind break.
- Manure applied to fields to 70 to 100 t/ha (30-40 t/ac) and left on the surface will reduce drifting. A coating of liquid hog manure may also work.

For assistance with soil erosion problems producers can contact their county agricultural fieldman, district agriculturist or soil conservation specialists from Alberta Agriculture Conservation and Development Branch or from the PFRA.

FERTILITY AND FERTILIZERS

SOIL TESTING AND SAMPLING GUIDE

Soil testing has become a very important tool for assessing soil fertility and arriving at proper fertilizer recommendations. It is also a valuable management aid for studying soil changes resulting from cropping practices and for solving specific cropping problems.

To make the most effective use of soil testing it is necessary to take proper and representative samples. Further information and guidance can be obtained by contacting a district agriculturist, fertilizer dealer, or one of the soil testing laboratories in Alberta. Private labs are listed in the yellow pages under Soil Testing and are located in Lethbridge, Brooks, Crossfield and Edmonton. The government laboratory, The Agricultural Soil and Feed Testing Laboratory, is located at 6909 – 116 Street, Edmonton, T6H 4P2. A $15 fee (cheques payable to Provincial Treasuer) at the Alberta government lab pays for analysis of one surface sample and two subsurface samples from the same field. Soil sampling kits for the government lab are available at district agriculturist offices.

Sampling Procedure and Equipment. Fields for spring seeding should be sampled after October 1 or in the spring (but then time is limited). Problem soil areas may be sampled any time. Frozen and water-logged soils should not be sampled because of the difficulty of obtaining a representative sample.

Fields with different crops or management should be sampled separately and fields larger than 25 to 30 hectares (60 to 75 acres) should be divided into two or more plots for sampling. Avoid unusual areas such as dead or back furrows, old straw, hay or manure piles, waterways, saline spots, eroded knolls, and old fence rows. Select 15 to 20 sampling sites in the field to be tested.

Take a soil core from 0-15 cm at each of the 15 to 20 sampling sites. For improved nitrogen evaluation particularly on irrigated soils or where problem soils are encountered, separate samples should be taken from 0-15 (surface), 15-30 and 30-60 cm (subsurface) depths at the sites. Analyses from the Soil and Feed Testing Laboratory are provided for one surface sample plus two subsurface samples. Place cores in clean pails or bags then mix cores taken from same depths, crushing lumps in the process.

Sampling Equipment. Representative soil samples can best be obtained by using core sampling tools. These are generally available on request from district extension offices and fertilizer dealers. A spade may also be used to take surface samples at 0-15 cm. Information on a depth sampler may be obtained from any soil testing laboratory.

Drying and Submitting. Remove one half kilogram or more of each soil sample and air dry to stop nitrate build-up. To air dry, spread a thin layer of soil on a clean piece of paper and dry at room temperature for 1-2 days. DO NOT DRY WITH ARTIFICIAL HEAT.

Place a plastic sample bag inside the sample box, then fill the box completely. Tie the bag and box securely and label each box with your name, address, postal code, sample number, and measurement of depth of the sample. Repeat these steps for each field sampled. When two or more samples are submitted, place the samples in a shipping container.

Provide complete information for each soil sample on the sheet supplied for samples to be sent to the laboratory of your choice. Where unusual problems exist, these should be noted in detail.

Private soil testing laboratories should be consulted when submitting samples.

NUTRIENTS MEASURED IN A SOIL TEST

The plant nutrients that are likely to be lacking in Alberta soils used for potatoes are nitrogen, phosphorus, and occasionally potassium. Sulphur is a macro-nutrient required in moderate amounts by crops, however, it is not normally deficient in areas where potatoes are grown. Few soils are so deficient in one or more of these nutrients that obvious deficiency symptoms other than those for nitrogen develop on the plants. Deficiencies of micronutrients have rarely been documented.

Fertilizer requirements will vary from field to field and from year to year, therefore soil tests should be used as a tool to determine the kind and rate of fertilizer to apply. General recommendations given for crops should only be used as a guide when a soil test is not available.

Nitrogen. The nitrogen test measures available nitrogen (nitrate) in the soil at the time of sampling. Therefore, to assess the nitrogen status of the soil for determining nitrogen fertilizer requirements, soil samples should be taken in late fall or early spring. Nitrate nitrogen moves readily with soil moisture and on irrigated soils soil samples should be taken to a depth of at least 0.5 metre. Soils that have recently been manured or broken from a legume or grass-legume mixture will release large amounts of nitrogen during the growing season. This information should be supplied with the soil samples so that nitrogen fertilizer recommendations can be adjusted.

Phosphorus. The level of available phosphorus in a particular field does not change dramatically from year to year unless very high rates of phosphate fertilizer or manure are applied. A soil test for phosphorus can be used as a guide to phosphate fertilizer requirements for two to three years. Periodic evaluation of the soil phosphorus level will provide a useful guide to changes in this nutrient over a period of time.

Potassium. Soils in southern Alberta are not generally deficient in potassium, but some soil types in west central Alberta and northeastern Alberta are often moderately low in available potassium. Most soils in southern Alberta are high in available potassium, but some sandy soils may be deficient for potatoes which have a very high potassium requirement. A soil test should be used to identify a need for the use of potassium fertilizers in a cropping program. Periodic soil tests will provide an assessment of changes in the potassium level in the soil over time.

Sulphur. Some soils in central, northern and western Alberta are deficient in sulphur. The test for sulphur is done in areas where it is known to be deficient and will be done in other areas upon request. Irrigated soil in southern Alberta receives about 20-50 kg/ha (18-45 lb/ac) of sulphur from each 30 cm of irrigation water applied, so is seldom deficient in sulphur. Most dryland potato farms in Alberta are in areas where sulphur is not deficient.

THE ROLE OF MAJOR PLANT NUTRIENTS IN POTATO PRODUCTION

There are basically two types of plant growth. The first is vegetative, which results mainly in an increase in size of plant parts and involves cell growth. Nitrogen plays a major role in this type of growth. The second type, differentiated growth, involves the formation of flowers, fruit and seeds. Phosphorus plays a leading role in this type of development.

Plants require 16 essential elements to function properly. Thirteen of these elements must be taken up from the soil. The other three: carbon, hydrogen, and oxygen, come from air and water. Some elements are taken up by plants in relatively large quantities (macronutrients); others in small or miniscule amounts (micronutrients). Specific roles of plant nutrients are complex and not all are well understood. Some of their basic functions and effects on plant growth may be helpful when observing crops.

Nitrogen. A deficiency of nitrogen can result in small leaves and stems, pale yellowish-green color, and reduced protein content. The lower leaves may be affected first, but other leaves follow. Yellowing progresses to drying up and shedding. Excess nitrogen results in succulent, weak stems and delayed maturity.

Phosphorus. This nutrient stimulates root formation and early plant growth, it also promotes seed and fruit formation and hastens maturity. A deficiency of phosphorus may result in smaller than normal plants or stunted growth. Purplish discoloration of mature leaves may occur on some crops.

Potassium. Unlike nitrogen and phosphorus, which make up part of the plant structure, potassium plays a regulatory role. But like the other two, it is also required in relatively large amounts. Potassium affects the appearance and disease tolerance of potatoes. Scorching or firing along the leaf margins of older leaves is the most common sympotum of potassium deficiency.

MICRONUTRIENTS

All macronutrients and micronutrients are required for optimum crop production. It is important to remember that the term micronutrient refers to the relative quantities required for plant growth and does not mean that they are any less important to plants than other nutrients. Plant growth and development may be retarded if any one of these elements is lacking in the soil or if a nutrient is not adequately balanced with other nutrients.

There are seven micronutrients required by potatoes. The types and amounts required are:

Boron	0.07 kg/ha (0.03 kg/ac)
Chlorine	27.0 kg/ha (ll.0 kg/ac)
Copper	0.07 kg/ha (0.03 kg/ac)
Iron	0.90 kg/ha (0.40 kg/ac)
Manganese	0.16 kg/ha (0.06 kg/ac)
Molybdenum	—
Zinc	0.09 kg/ha (0.04 kg/ac)

Soil tests aid in determining whether or not a particular nutrient is responsible for poor production and provides the basis for deciding the type and amount of fertilizer needed to correct a nutrient shortage. One of the more serious limitations of the soil test has been the lack of suitable tests for micronutrient availability. Only in the last few years have soil tests been accepted for use in predicting the availability of copper, iron, manganese and zinc. The results of a soil test are meaningful only when they can be related to field conditions. The relationships can only be established through correlating soil tests with fertilizer trials in the field on soils with both deficient and adequate nutrient levels. The results obtained are used by soil laboratories as a basis for making fertilizer recommendations. At present, it appears that the soil tests for micronutrients on the high pH soils of southern Alberta do not accurately predict the available micronutrient levels in soil. If this is true, then only plant tissue testing would be acceptable in identifying micronutrient deficiencies. Further testing is being done to verify this.

Plant tissue tests also aid in determining if a particular nutrient is responsible for poor crop growth; however, it is difficult to predict the amounts of nutrients needed to correct a shortage from a tissue test. As with soil analysis, tests involving plant tissue must be calibrated with field fertilizer trials, a complex process. The reason for the difficulties is that measured nutrient concentration, which is the basis of the tests, varies considerably with the stage of plant development and the portion of the plant sampled.

Micronutrients may be soil or foliar applied in salt or chelated forms at very low rates. Soil applied micronutrients may be broadcasted and incorporated or banded into the soil. They may be applied individually or mixed with other fertilizers. There is conflicting information as to which types of micronutrient fertilizers are most effective and whether soil or foliar applications of micronutrients are best.

Micronutrient fertilizer trials have been conducted on potatoes varieties at a number of locations in Alberta. To date, no significant response has been obtained with micronutrient fertilizers even when soil tests indicated low levels of micronutrients. Therefore, applying micronutrient fertilizers based solely on a soil test is not recommended.

Micronutrient fertilizer recommendations should be based on soil tests, tissue tests and close visual examination. If micronutrient fertilizers are used, initial applications should be put on in test strips in a field to verify if a yield response has occurred. As some crops are injured by very low levels of micronutrients care must be taken not to over apply these expensive nutrients.

Soil Additives. A number of soil additives have been promoted over the years. Some have been tested and to date soil additives and miracle fertilizers have not shown a yield advantage. New products which make great claims that have not been scientifically tested should be treated with skepticism. Farmers who want to try using unproven products should do so in test strips and on a trial basis only.

COMMERCIAL FERTILIZER RECOMMENDATIONS

Pricing Fertilizers. The Fertilizer Act requires that fertilizers be labelled according to their guaranteed analysis in terms of percent by weight of nitrogen (N), phosphate (P_2O_5) and potash (K_2O). For example, 100 kg of 11-51-0 contains 11 kg of nitrogen (N), 51 kg of phosphate (P_2O_5), and 0 kg of potash (K_2O).

Fertilizer should be purchased on the basis of the price per kilogram of nutrient, not price per tonne of material.

Fertilizer Recommendations. Tables 6 and 7 show general fertilizer recommendations for increasing the three major nutrients as indicated by soil tests for potatoes grown under irrigation. These rates are based only on the level of nutrients in the soil. Adjustment to these recommendations would need to be made depending on the other factors such as legume plowdown and manure application and the amount of irrigation.

Nitrogen Fertilizer. Nitrogen moves readily in moist soil and therefore need not be applied near the seed pieces to be effectively used. However, surface application or shallow incorporation can result in reduced uptake if the seedbed remains dry during the early growing season. Nitrogen applied as anhydrous ammonia in a band at a depth of 10-15 cm or banded at planting may be more effective when the surface soil remains dry for an extended period during the early growing season.

Nitrogen fertilizers can be applied in either late fall or spring with similar results. Nitrogen applied in the fall has a greater opportunity to move deeper into the root zone and therefore may be more effective than spring broadcast nitrogen under dry conditions. It is preferable to delay fall application of nitrogen until the soil temperature has declined to 10°C or less. Following are common nitrogen sources available with comments on their uses and activity.

Ammonium nitrate (34-0-0) is less subject to volatilization than urea when surface applied without incorporation; however, it is subject to leaching losses on sandy soils. It is used with ammonium phosphate to make 23-23-0 and 26-13-0.

Ammonium sulphate (21-0-0-24S) contains 24% sulphur and is mixed with ammonium phosphate to make 16-20-0. It is more acidifying than other nitrogen fertilizers and should not be used continuously on acid soils.

Urea (46-0-0)is subject to evaporation when not incorporated into the soil and significant losses can occur if applied under warm dry conditions on sandy soils, and on soils with a pH of 7.5 or higher. It is used with ammonium phosphate to form 27-27-0.

Anhydrous ammonia (82-0-0) is injected at a depth of 10-15 cm with a narrow shank applicator set at 40 cm spacing. The soil must be worked sufficiently to close behind the shank and prevent escape of ammonia gas. It is suitable for fall or spring application. Anhydrous ammonia is a pressurized gas and should be HANDLED WITH CAUTION. For further information see your fertilizer dealer or obtain the following publication: Agriculture Ammonia Safety, The Fertilizer Institute, 1015 – 18th Street NW, Washington, DC, U.S.A. 20036.

Urea-ammonium sulphate is available in dry form (34-0-0-11S) or as a solution (20-0-0-5S) and may be used where sulphur is required.

Urea-ammonium nitrate solutions (28-0-0 and 32-0-0) can be uniformly applied and are easy to handle; however, losses may occur if sprayed on a heavy trash cover.

Phosphate Fertilizer. Phosphate fertilizer does not move readily in soil so it must be placed near the seedling roots to be most effective. Phosphate is most readily available in several forms of monoammonium phosphate (11-48-0,11-51-0, 11-54-0 and 11-55-0).

Diammonium phosphate (18-46-0) can also be used if a higher ratio of nitrogen is required. There is evidence indicating that diammonium phosphate is slightly less efficient than monoammonium phosphate on calcareous soils.

Potassium Fertilizer. Potassium will move in the soil more readily than phosphorus, but for annual crops, potassium fertilizers are more efficient when drilled near seed pieces. Broadcast applications can be used at about twice the rate used for drill-in applications and can be made in either fall or spring.

Muriate of potash (0-0-60 or 0-0-62) is the most commonly available potassium fertilizer. It is used directly as a broadcast application or mixed with phosphate and nitrogen fertilizers to make fertilizer grades such as 10-30-10, 8-24-24, 13-13-13, and others. The cost of potash in some of the blends tends to be much higher than in 0-0-60 or 0-0-62 forms.

Sulphur Fertilizer. Sulphur in the sulphate form moves readily in moist soils. Therefore soluble sulphate fertilizers provide a readily available sulphur source either as broadcast or drill-in applications. Irrigation water in southern Alberta supplies about 10-20 kg/ha (4-8 kg/ac) for every 10 cm of irrigation water applied.

Sulphur fertilizers include ammonium sulphate (21-0-0-24S) and urea-ammonium sulphate available as 34-0-0-11S or in solution as 20-0-0-5S. The urea forms are less acidic and therefore recommended for use on acid soils that are sulphur deficient. Sulphur can also be applied as elemental sulphur (90%) or as gypsum (18%).

Fertilizer Placement and Application. The following are brief descriptions of methods commonly used to apply fertilizer to potatoes.

Broadcasting is a relatively cheap method of applying fertilizers, however, it is not the most efficient method where rows are spaced far apart and plant roots do not meet between rows.

Top dressing refers to broadcasting fertilizer on a field when a crop is growing. The fertilizer is normally not incorporated but irrigation may be used after fertilization to move nitrogen into the soil. Top dressing is normally restricted to ammonium nitrate as other forms of nitrogen are likely to cause burning of the leaves. Top dressing,

Table 6. Soil Test Ratings and General Fertilizer Recommendations for Nitrogen and Phosphorus for Irrigated Potatoes in Alberta*

Soil Test Rating		Nitrogen lb/acre N		Nitrogen Recommendation	Phosphorus lb/acre P	Phosphate Recommendation[1, 2]	Potassium lb/acre K	Potash Recommendation[1]
		0-6 in	0-24 in	N (lb/acre)	0-6 in	P_2O_5 (lb/acre)	0-6 in	K_2O (lb/acre)
Deficient	Low –	0-7	0-17	170	0-10	90	0-50	100
	Low	8-13	18-32	160	11-20	80	51-100	80
	Low +	14-20	33-50	150	21-25	70	101-150	60
Moderately Deficient	Medium –	21-30	51-70	135	26-30	60	151-200	50
	Medium	31-40	71-90	120	31-40	50	201-250	40
	Medium +	41-50	91-115	100	41-50	40	251-300	30
Marginal to Adequate	High –	51-60	116-140	80	51-70	30	301-400	0
	High	61-75	141-170	50	71-90	20	401-600	0
	High +	75+	170+	20	91+	10	601+	0

Table 7. Soil Test Ratings and General Fertilizer Recommendations for Nitrogen and Phosphorus for Irrigated Potatoes in Alberta*

Soil Test Rating		Nitrogen kg/ha N		Nitrogen Recommendation	Phosphorus kg/ha P	Phosphate Recommendation[1, 2]	Potassium lb/acre K	Potash Recommendation[1]
		0-15 cm	0-60 cm	N (kg/ha)	0-15 cm	P_2O_5 (kg/ha)	0-15 cm	K_2O (kg/ha)
Deficient	Low –	0-8	0-20	190	0-10	100	0-55	110
	Low	9-15	21-35	180	11-20	90	56-110	90
	Low +	16-25	36-55	170	21-30	80	111-170	70
Moderately Deficient	Medium –	26-35	56-80	150	31-35	70	170-225	55
	Medium	36-45	81-100	130	36-45	65	226-280	45
	Medium +	46-55	101-130	110	46-55	45	281-340	35
Marginal to Adequate	High –	56-70	131-160	90	56-80	30	341-450	0
	High	71-85	161-190	60	81-100	20	451-670	0
	High +	86+	191+	20	100+	10	671+	0

* Source: Alberta Agricultural Soil and Feed Testing Laboratory.

[1]Recommendations listed are general; specific recommendations will vary depending on: location in the province, soil zone, soil texture, soil pH, past field cropping history and free lime in soil.
[2]Recommendations for phosphate are for row or band application, rates for broadcast applications should be double that in the table.

banding and fertigation are primarily used to apply nitrogen to maturing crops when amounts of nitrogen may be low, yet the crop still has a high nitrogen demand.

Drilling refers to applying fertilizer near the seed in the same drill row or furrow. Applicators should be set so that as little fertilizer as possible is placed directly with the seed pieces. Some mixing of seed, fertilizer and soil should occur. Phosphorus fertilizers are commonly applied to large seeded vegetable crops by drilling.

Banding is the application of fertilizer in a continuous band to the side and below the seed at the time of planting. Banding is an efficient method of applying phosphorus fertilizer. Side-dressing refers to banding fertilizers in the soil to the side of the crop row after plants are established. Care should be taken not to damage crop roots.

FERTIGATION AND FOLIAR FEEDING

Fertigation. Fertigation is a method of applying liquid fertilizers through an irrigation system. The most commonly used fertilizer for fertigation is nitrogen as 28-0-0. The advantages and disadvantages of using fertigation as a method of applying nitrogen are listed below.

Advantages	Disadvantages
It is easy to apply. Uniform application.	The form of nitrogen fertilizer used is more expensive.
In season nutrient deficiencies can be corrected.	This requires foliar testing to recognize the deficiencies.
Improved efficiency of nitrogen use on coarse textured soils.	No difference in efficiency of nitrogen fertilizer use on medium textured soils.
Nitrogen can be applied as the crop needs it.	Nitrogen applied after the commencement of flowering of late potatoes will delay maturity, reduce the dry matter content, and increase the occurrence of hollow heart.

Phosphorus applied through fertigation on cereals has not been shown to be any more advantageous than granular phosphate banded in the spring. Because phosphorus does not move in the soil and is required early in the growing season it is not considered compatible with fertigation or foliar applications.

Foliar feeding. Foliar feeding is a technique of applying soluble fertilizers in a spray form It is promoted by some fertilizer dealers; however, there are no data available to suggest it is economically superior to more conventional techniques.

MANURE

Animal wastes can add both organic matter and nutrients to the soil. Manure can be used as a source of nitrogen, phosphorus and potassium. When manure has to be hauled long distances, its benefits are outweighed by trucking costs because of the high rates applied.

The amount of nutrients in manure will depend on several factors: the type of animal, the type of feed, the feeding method, age of the manure, and method of storage. Fresh manure is usually high in nitrogen, but nitrogen can volatilize into the air and be leached out by rain. The levels of nitrogen in old manure may be low. As a rough guide, a grower could expect that a 10-15 tonne application of pig, beef or dairy manure would add about 20 to 70 kilograms each of nitrogen, phosphorus and potassium. When using manures in combination with commercial fertilizers, reduce the amounts of fertilizer by taking into account the nutrients added by the manure.

Since fresh manure contains seeds, caution is advised when buying and spreading manure. Most weed seeds are still able to grow after passing through an animal and can infest clean land. Manure that is known to have weed seeds in it is usually suitable for spreading after it has been piled for a period of one or two years. On occasion manure especially from feed lots can contain a high level of salts, which if added to a soil already slightly saline could further add to the soil salinity.

THE EFFECTS OF NUTRIENTS ON QUALITY

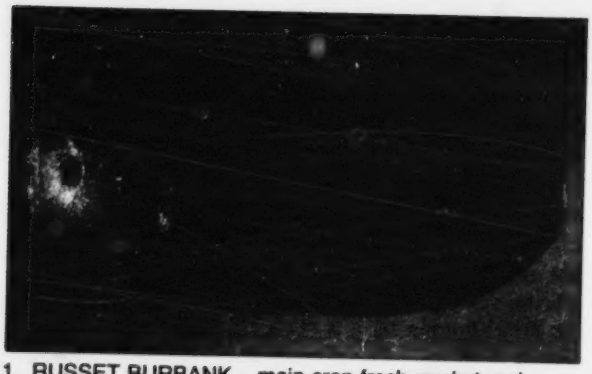
Nitrogen. Excessive levels of nitrogen initially or applied during the growing season will delay the maturity of potatoes. One set of experiments over six years by Irrigation and Conservation Division staff of Alberta Agriculture included a treatment where 60 kg/ha (25 kg/acre) of extra nitrogen was applied to potatoes at the end of June or the first of July. This treatment would be similar to fertigation. The potatoes had also received about 120 kg/ha (50 kg/acre) of N at seeding.

The effect of the additional N was:

- increased marketable yield by 10-16%
- increased yield of extra large tubers by 120-200%
- reduced the yield of small and Canada #1 small tubers by 10%
- reduced specific gravity
- reduced the dry matter content of tubers by 0.5% on Russett Burbank and Norchip, with little difference on Norlands
- increased the prevalence of small brown spots and hollow heart in the tubers.

Other effects of the midseason application of nitrogen was to increase the tubers protein content and reduce the sugar content. Reports are inconclusive as to whether high levels of nitrogen fertilizer increase the darkening of potatoes after harvest. It has been reported that extra nitrogen applied at seeding time increased yield because more tubers were formed (Agriculture Canada, Lethbridge).

POTATO CULTIVARS

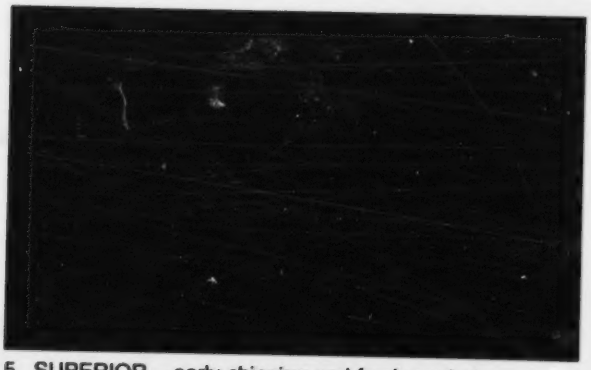


1. RUSSET BURBANK – main crop fresh market and french fry

2. NORCHIP – main crop chipping

3. NORGOLD RUSSET – mid-season fresh market

4. NORLAND – fresh market



5. SUPERIOR – early chipping and fresh market

6. SHEPODY – mid-season french fry

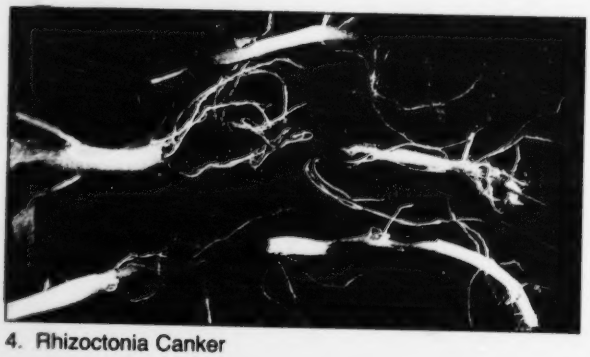
7. CARLTON – early fresh market

DISEASES OF POTATOES

1. Bacterial Ring Rot – tuber symptoms

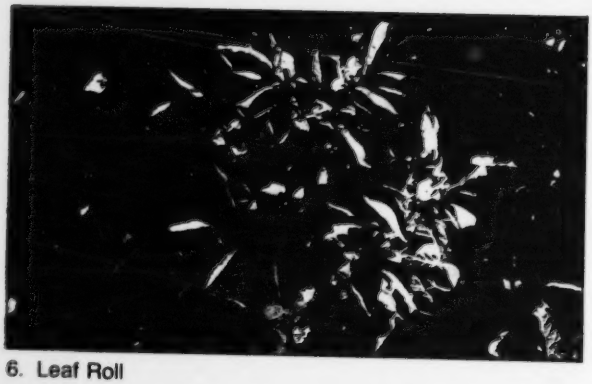
2. Bacterial Ring Rot – milky ooze from stem

3. Lenticular Soft Rot



4. Rhizoctonia Canker

5. Early Blight



6. Leaf Roll

13. Tubers with two storage fungal diseases (Silver Scurf, Skin Spot) plus pressure bruise. Peeled tubers with these disorders cause problems for processors.

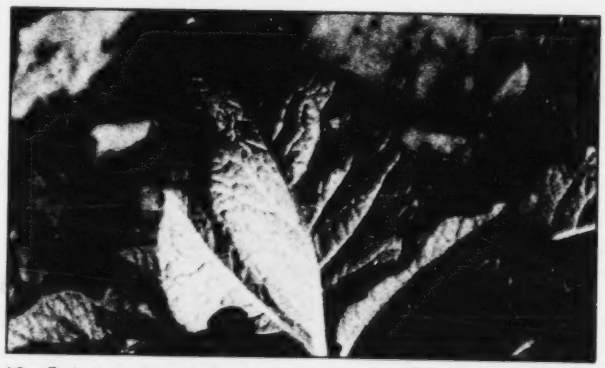
DISORDERS OF POTATOES

7. Tordon injury on foliage

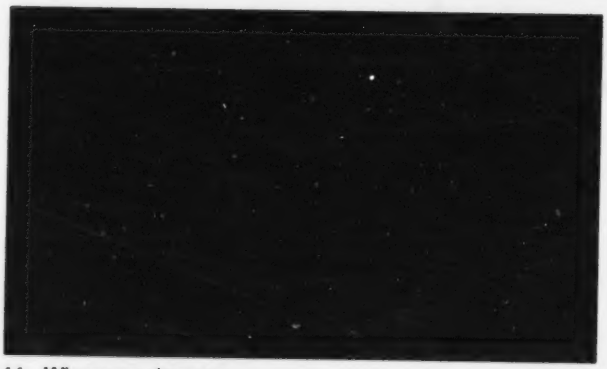
8. Secondary tubers and knob formation caused by heat and moisture stress on Russet Burbanks.

INSECT PESTS

9. Colorado Beetle – larvae and adult



10. Colorado Potato Beetle – eggs on underside of leaf



11. Wireworm damage

12. Wireworms

Phosphorus. Phosphorous fertilizer has not been found to influence quality of tubers; however, reports from Europe indicate the addition of high rates of phosphate fertilizer reduces bruising of tubers.

Potassium. Potatoes have a higher requirement for potassium than most other crops. Experiments in the U.S.A. have indicated that potassium applied to soils that were not regarded as deficient reduced disease levels in potatoes and thus increased yield. Yield responses to potassium fertilizers have only occasionally been reported in Alberta. Experiments from Europe indicate that the addition of potassium fertilizers reduced the number of bruised tubers and tubers which were subject to inner blackening. Potassium slightly decreases the dry matter content of tubers. An average of 46 experiments from Europe report that an addition of 240 kg/ha K_2O (210 lb/ac) reduced the dry matter content of tubers by 0.5%.

IRRIGATION

About three-quarters of Alberta'a total potato area is grown in southern Alberta and irrigated. Some potato fields in central and northern Alberta also receive irrigation.

Adequate irrigation of potatoes is necessary to produce high yields of top quality tubers. Increased use of irrigation and improvements in irrigation equipment and management have been the major reasons why average yields of potatoes in Alberta have increased from about 11 t/ha (4.5 t/acre) in 1953 to 1958 to an average of 25 t/ha (10 t/acre) in 1980 to 1984.

IRRIGATION MANAGEMENT AND TIMING

Potatoes tend to be more sensitive to soil moisture stress than most crops and therefore require light frequent applications of water, especially after tuber formation.

When optimum soil moisture conditions are continuous, as compared to intermittent, the average size of the potato tubers is reduced, but the number and yield of potato tubers produced is increased and the shape of the tubers improved. Excess irrigation of potatoes may result in disease and possible creation of water tables which lead to salinity problems.

With optimum soil moisture conditions and soil fertility levels throughout the growing season, the yield of commercial potatoes can range from 35 to 45 t/ha (14 to 20 t/ac). Total consumptive use water for the season is about 500 mm.

Potatoes tend to grow best in soils that are coarse to medium textured (loamy sand, loam) but can be grown on finer textured soils as long as they are well drained.

The ideal piece of land should have gently sloping topography to allow for good drainage and uniform irrigation.

The availability of soil moisture for use by potatoes and other crops varies with soil texture:

Loamy sand - fine sandy loam	80-140 mm/m
Loam	160-200 mm/m
Clay loam - silty clay loam	185-220 mm/m

The potato root zone is shallow compared to other crops. Potato roots go down to about 0.80 m which is shallower than cereals (1.0 m) or alfalfa (1.2 m or more). These rooting zones are depths for irrigation scheduling and do not refer to maximum rooting depth for the crop.

The allowable soil moisture depletion level refers to the percentage or amount of soil moisture which can be extracted from the root zone without causing a significant yield reduction of quality tubers. The recommended allowable depletion level is 30% for seed potatoes and 35% for commercial potatoes. This means that after field capacity of soil has been reached, only 30 to 35% of the water stored in the root zone can be used by the crop before measurable reduction in yield or quality occurs, unless more moisture is received.

The timing of an irrigation and the amount of water to be applied to a potato crop depends on its rooting depth, water holding capacity of the soil, and the level of depletion the potato crop can tolerate. For example, a loam soil holds 165 mm/m of available moisture for plant use or about 130 mm/0.8 m for the entire root zone.

Since the allowable depletion level for commercial potatoes is 35%, then 45 mm of water is available for plant use.

Daily moisture use varies with the stage of potato development (Figure 7). During the early stages of development, consumptive use is low but as the crop matures, its average water use increases to 6 mm/day If 45 mm of water is available for crop use, then an irrigation will be required every seven or eight days during the peak period of consumptive use (assuming the weather is warm and no rain falls). An application of about 45 mm of water (net) will be required to refill the root zone to field capacity.

Coarse textured soils have about 25-40 mm of water available in the root zone which can be safely depleted between irrigations. Fine textured soils have about 50-60 mm of available moisture in the root zone. As texture changes so does the amount of water which can be added with each irrigation and the time interval between irrigations.

The simplest way to determine soil moisture content is to use the "feel method" (Figure 8). By squeezing a handful of soil firmly, the amount of moisture present can be determined by the feel and appearance. The moisture content of each quarter of the root zone should be determined in order to calculate the moisture present in the entire root zone.

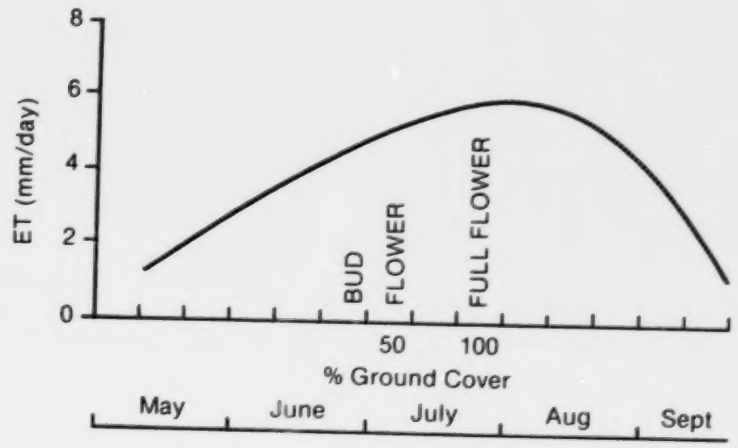


Figure 7. Evapotranspiration during the growing season.

	PERCENT OF AVAILABLE MOISTURE REMAINING	Feel or Appearance of Soils		
		SANDY LOAM	LOAM	CLAY LOAM
DO NOT IRRIGATE	At Field Capacity 100	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Same as sandy loam.	Same as sandy loam.
DO NOT IRRIGATE	75 to Field Capacity	Forms a weak ball, breaks easily, will not slide.	Forms a ball and is very pliable; sticks readily if relatively high in clay.	Easily ribbons out between fingers, has a slick feeling.
IRRIGATE SPEC. CROPS	50 to 75	Tends to ball under pressure but seldom will hold together.	Forms a ball; somewhat plastic; will sometimes stick slightly with pressure.	Forms a ball, will ribbon out between thumb and forefinger.
IRRIGATE	25 to 50	Still appears to be dry, will not form a ball with pressure.*	Somewhat crumbly, but will hold together from pressure.	Somewhat pliable, will ball under pressure.*
IRRIGATE	0 to 25	Dry, loose, single-grained, flows through fingers.	Powdery, dry, sometimes slightly crusted but easily breaks down into powdery condition.	Hard, baked, cracked. Sometimes has loose crumbs on surface.

* Ball is formed by squeezing a handful of soil firmly.

Figure 8. Practical interpretation chart for available soil moisture.

The most critical period for avoiding moisture stress in potatoes is from just before flowering to the beginning of the vine ripening. Shortage of irrigation water during this period will cause reduced yield and reduced tuber quality.

THE EFFECTS OF IRRIGATION ON QUALITY

Table and Processing Potatoes. Frequent irrigation to avoid periods of moisture stress will influence the yield, grade, number, size and the quality of the tubers. The effect of maintaining the available moisture above 60% as compared with maintaining it above 40% was measured on three varieties of potatoes for six years by Alberta Agriculture, Irrigation and Conservation Division staff. The effects of more frequent irrigations to maintain available water above 60% were:

- increased marketable yield, by 7%, 5% and 0% on Russett Burbank, Norland and Norchip potatoes respectively
- increased yield of small and Canada #1 small tubers by 23%, 40% and 10% on Russett Burbank, Norland and Norchip respectively
- increased dry matter of Russett Burbank, a late maturing variety, and little difference on Norland and Norchip
- increased presence of small brown spots in the centre of the tubers of Russett Burbank potatoes
- reduced protein content of tubers
- reduced number of irregular shaped culls and Canada #2 tubers.

Seed Potatoes. Frequent irrigation and avoiding moisture stress at the time of tuber initiation increases the number of tubers and reduces the average size of the tubers. This is important for a seed producer who wishes to produce small whole tubers.

IRRIGATION METHODS

Surface methods of irrigation are usually limited to slopes of less than 2% but can be used on deep rooted crops that are not watered frequently. Sprinklers generally can be used on slopes of up to about 10% with no problems although some centre pivot systems can work on steeper land.

The infiltration rate or rate at which soil can take in water will affect the selection of the type of irrigation system. Fine textured soils accept water more slowly and are better suited to surface irrigation methods. Coarse and medium textured soils accept water quickly and are better suited to sprinkler systems.

Surface Irrigation. Furrow irrigation is the only surface method that can be used on potatoes. The best way of distributing water to the individual furrows is with gated pipe; however, an earth head ditch with syphon tubes can also be used at a much lower cost. The gated pipe system can be operated by gravity although some situations would require a low head pump. Aluminum or PVC plastic are the most popular pipe materials. Gates are located in the pipe to fit furrow spacings from 60-90 cm.

The use of gated pipe as compared to an open ditch reduces the amount of land lost to ditches, reduces evaporation and seepage losses, and reduces the demand for labor and for the irrigator's attention. The irrigator has good water control and the ability to distribute water uniformly to the furrows.

Wheel-Roll Irrigation. This system consists of a lateral pipe acting as an axle for steel wheels, which are spaced along the lateral the same distance as the sprinkler heads, 12 m apart. The lateral is rolled from one set to the next which reduces the labor requirement as compared to hand move systems. After a set is completed (6, 8 or 12 hour) the system is drained and moved to a new set 18 m away. The most common wheel-roll system used in Alberta for potatoes would have four 400 m laterals on a quarter section of land with the mainline running down the center of the field. With 22 sets per 400 m (¼ mile) it takes 5-10 days to cover a field. Where only two 400 m laterals are used per quarter section the coverage time increases to 10-20 days which is normally too long for potato production.

Centre Pivot. The system consists of a lateral pipe mounted on high towers and attached to a pivot point. Because it irrigates while moving it is capabie of doing a more uniform job than machines that do not move while irrigating. Some operators use one centre pivot lateral on two circles and tow it from one pivot point to another. This is not recommended where both circles are growing the same crop. Most potato growers use one system per quarter section.

Centre pivots can be driven by compressed air, water, oil or electricity. Currently most of the systems sold have electric drive. Pivot systems can have only one tower 90 m long or can have up to 18 or 20 towers reaching up to 800 m and covering about 200 ha (500 ac).

The corners of a square field cannot normally be irrigated with a centre pivot; however, some pivot systems irrigate the corners by the use of a corner boom which swings out and then retracts as the machine passes the corner. By using this type of mechanism, about 60 ha (155 ac) of a quarter section can be irrigated. The cost of adding a corner tower is about $2400 ha ($1000/acre) compared with about $1300 ha ($500/acre) for the circular part of the system.

Pumps and Power Units. The heart of any sprinkler irrigation system is the pumping unit. The pump and power unit both must be selected to match the particular conditions under which they will be operated. No one pumping unit is good for a wide variety of situations.

Natural gas and electricity are the cheapest energy sources when the cost of energy alone is considered. Electricity has the advantage of convenience and less maintenance, but the added disadvantage of the high cost of installing

three-phase power. Diesel fuel and propane are also used frequently, but their cost is significantly higher; however, neither of them have the high cost associated with installing an electric or a natural gas line.

Capital and Operating Costs of Irrigation Systems. The following table compares capital and operating costs for various irrigation systems.

Assistance. Assistance with design of an irrigation system, drainage of problem areas and with irrigation scheduling is available from Alberta Agriculture irrigation specialists with offices located in Airdrie, Brooks, Bow Island, Lethbridge, Medicine Hat, Strathmore, Taber and Vauxhall. The Airdrie office serves central and northern Alberta.

Table 8. Comparison of Irrigation Systems 1986

Assumptions:
Water available at the edge of field
Net water applied 30 cm. (12 inches)
64 ha (160 acres) irrigated by wheel rolls & surface methods
42 ha (132 acres) irrigated by center pivots
Cost of installing electric or natural gas line not included.
Annual water rates of $18-$38/ha ($7-$15/acre) not included.

Cost Factors:

Natural Gas (GJ)	2.70
Propane (L)	0.24
Diesel (L)	0.41
Labor ($/hr)	6.00
Interest (%)	11.50

System	A Cap.* Cost $/ac ($/ha)	B Ann.* Fixed $/ac ($/ha)	C Ann.* Labor $/ac ($/ha)	D Repair & Maintenance $/ac/yr ($/ha/yr)	E Energy Costs $/ha/yr Elec A	Elec B	N Gas	Prop	Dies	Total** $/ac/yr ($/ha/yr) Min	Max
High Pressure Pivot 480 kPa	1240 (520)	181 (73)	5 (2)	18 (7)	55 (22)	40 (16)	28 (11)	76 (31)	74 (30)	232 (94)	279 (113)
Low Pressure Pivot 340 kPa	1183 (479)	171 (69)	5 (2)	18 (7)	39 (16)	29 (12)	21 (8)	54 (22)	53 (22)	215 (87)	100 (247)
4-Wheel Roll 12 hour sets	897 (363)	131 (53)	16 (6)	12 (5)	52 (21)	35 (14)	25 (10)	66 (27)	65 (26)	180 (73)	222 (90)
Trickle 280 kPa	3211 (1300)	653 (264)	4 (2)	23 (9)	24 (10)	17 (7)	13 (5)	32 (13)	31 (13)	692 (280)	711 (288)
Gated Pipe (Gravity)	1191 (482)	144 58	16 (6)	9 (4)	0 0	0 0	0 0	0 0	0 0	168 (68)	170 (69)

* These costs are averages for all fuel types. Annual fixed costs and repair and maintenance costs vary significantly from one fuel type to the next.
** Rebates and tax reductions are applied to the following base energy rates in the final calculations.
*** Total min-max cost ranges calculated by adding B + C + D + the min max in E.

NOTE:

$/ac and $/ha

are reversed in Table 8

PEST MANAGEMENT

Potato growers and farmers in general are becoming increasingly familiar with the term pest management as opposed to pest control. All potato growers know that weeds, insects and disease are not controlled in the sense that they are eliminated and that growers can grow potatoes with manageable numbers of various pests and still produce profitable yields. Only one group of potato growers must have a zero level of pests, and those are the Elite seed growers, since seed regulations have a zero tolerance of visible diseases in the Elite classes.

The importance of cultural methods in pest management needs to be stressed. Registered pesticides obviously have a role in controlling pests like weeds, Colorado potato beetle and seed piece decay; however, cultural and general management practices play an equally important role. Consider how the following can influence the incidence of weeds, insects and diseases: crop rotation, soil texture and drainage, certified seed, sanitation, storage ventilation and temperature control, cut seed-piece suberization, cultivation and hilling, fertilizer and irrigation management, vine killing, and cultivar selection. All of these play a role in pest management and are used by growers along with chemical pesticides to manage pest levels within acceptable limits.

NOTICE

CONFIRM ALL PESTICIDE RECOMMENDATIONS PUBLISHED IN THIS MANUAL WITH THE PRODUCT LABEL. SHOULD RECOMMENDATIONS DIFFER, THE PRODUCT LABEL IS THE OFFICIAL GUIDE TO THE USE OF A REGISTERED CHEMICAL.

USE OF CHEMICAL PESTICIDES

PERSONAL SAFETY

The usefulness of pesticides lies in their ability to interrupt the life processes of plant and animal pests. However, these chemicals can have fatal effects on the life processes of humans and other animals. BE OVERLY CAUTIOUS AND HANDLE ALL PESTICIDES WITH RESPECT. The use of agricultural chemicals is increasing annually, both in total acreage treated and in the number of new compounds being introduced for the control of various pests. As a result, farmers are being exposed to a greater quantity of pesticides, some of which may be deadly.

Growers applying pesticides should have proper protective clothing and a respirator to minimize the exposure to pesticides during mixing and application. Safe storage and safe disposal of surplus chemicals are required to avoid accidents.

Each person involved in the handling and application of pesticides must be vigilant and constantly aware of the seriousness of swallowing or absorbing even a tiny amount of these chemicals. Farmers, the major pesticide users, are exposed to pesticides at various times. The major risk occurs during handling, storage or clean-up operations. It is important to know that chemicals can get on and into the body by breathing, by eating and by absorption through skin and eyes, or injection through the skin.

Please consult the publication *Guide to Crop Protection in Alberta - Part 1 Chemical* for detailed information on protective devices for use when handling or applying pesticides.

RE-ENTRY TO TREATED AREAS

Pesticide poisoning may occur where workers enter fields too soon after pesticides have been applied. Such poisoning can result from handling treated plants or from inhalation of pesticide vapors. Follow label recommendations. The following minimum intervals are recommended.

24 Hours	**48 Hours**
Lannate	Guthion
Phosdrin	Temik
Supracide	
Furadan	

STORAGE OF PESTICIDES

Pesticides should always be stored in a cool, dry, locked and well ventilated area away from food and drink used for human or animal consumption. It is advisable to select a building or part of a building which is separated from human and animal quarters. The building should be posted with a warning sign, "Chemical Storage — Authorized Persons Only" in block letters, clearly visible. It should be built of fire resistant materials. Wastes should not drain to any other disposal system but one specifically designed for pesticides. Protective clothing, a respirator and a first aid kit should be available for the storage area but kept separately to prevent contamination.

Do not remove more material from storage than you can use in a day and return unused quantities immediately after completion of spray operations.

Pesticides should always be stored in the original container no matter how small a quantity requires storage. If a container is damaged and losing its contents, repack and label the package properly. Herbicides should always be stored separately from other types of pesticides and fertilizers to prevent cross contamination or danger of fire or explosion.

DECONTAMINATION

Decontamination of oneself or another person may be necessary upon exposure to concentrated pesticide

material as it comes from the can and before mixing. Contaminated clothing must be removed and stored in a plastic bag until it can be washed. Wash the contaminated area rapidly and thoroughly with detergent and water. Rinse thoroughly. Wash again and rinse. Now wash the contaminated area with rubbing alcohol to remove any remaining pesticides.

If a pesticide is spilled inside a building, you may need to wear protective clothing and probably a respirator. LET SOMEONE ELSE KNOW WHAT YOU ARE DOING AND HAVE THEM STAND BY OUTSIDE THE BUILDING. Check the label again if you do not remember details about the chemical. Begin by soaking up excess liquid with sawdust, rags, powdered clay, dirt or commercial cleaning compounds. Sweep up material and put it into a plastic bag for disposal by burning or by burying it in at least 45 cm of soil in an area that will not contaminate the sewage disposal system or ground outside the building. Put the contaminated dustpan and broom or brush into a plastic bag and keep for use with pesticides only. If the spill occurs outside on the ground, cover with soil and allow the pesticide to soak into the ground. DO NOT use this as a method of disposing of excess amounts of pesticides.

DISPOSAL OF CONTAINERS

Where pesticides are used there is invariably a container that ends up empty and must be dealt with. In many cases, there will also be some surplus spray mixture left in the sprayer tank. These materials present a disposal problem. This section deals with some common methods of disposal which are not ideal but at the moment there are no better practical alternatives to offer.

Burying Containers. A very common method used on farms in the past has been to pry off the lid, wash the container thoroughly and re-use it for other purposes. With low toxicity materials this was tolerable, however, it is inherently dangerous and is an irresponsible approach. A better method is to decontaminate the container by rinsing it with water and pouring the resulting solution into the spray tank. The partially clean container may then be crushed and buried. The crushing is important to prevent an unsuspecting person from discovering and using the container at a later date. A suitable burial site should have all of the following characteristics:

- Be on high ground where water will not collect.
- Sloped away from any collection area where water (either surface or subsurface) will collect which could conceivably be used for drinking by man or animals.
- The soil should be 3 to 4 m deep above rock or sand where lateral movement of water could occur.
- The site chosen should be in an area that would never be used for farming or building, or as a well, pond, etc.

The site should be fenced and identified by signs warning away visitors or trespassers. Numerous counties have established special sites for the disposal of pesticide containers (metal and plastic) which are eventually recycled. Growers should determine the location of these disposal sites and deliver empty pesticide containers to it.

Burning Containers. Not all combustible containers should be burned. Do not burn containers that have held highly volatile products or materials which are highly toxic in the vapor phase to either plants or animals. Bury these containers in a waste disposal area. Other containers made of paper, cardboard, cloth, other plant fibre and certain plastic cans should be burned in the waste disposal area.

Make sure the burning site is a safe distance away and downwind from residences, other human activity, animals, crops and other valuable plants. Stay upwind from the burning and avoid any contact with smoke as it may be very poisonous. Bury the ashes after burning.

DISPOSAL OF SURPLUS MIXED HERBICIDES

The methods developed to handle this problem are inadequate. For practical purposes the best answer is to try not to mix more than you need. When this is not possible the surplus material must be dumped. It is very important that such dumping be done in a special place, not in the farmyard. It should be in a waste area away from people or crops. The site should meet all the drainage criteria mentioned for a container disposal site. Remember that the material dumped may sterilize the soil for a number of years.

It is hoped that in the future a system will be developed whereby the concentrated pesticide may be metered into the sprayer line just before the boom, and the tank would contain only clean water. Surplus material would remain in the original container and be returned to storage for later use. This makes sense both from the standpoint of avoiding contamination and also would avoid wastage of expensive materials.

RELATIVE TOXICITY OF PESTICIDES

The toxicity data are based on tests with rats and rabbits and are considered relevant to all mammals including human. The principal source of information for this table is *Acute Toxicity Data for Pesticides (1970)*, R. Ben-Dyke, D.M. Sanderson and Diana N. Noakes. The following categories have been used: Dermal - LD50, 0-200, very toxic; 200 - 1,000, moderately toxic; 1,000 up, slightly toxic. Oral - LD 50, 0-50, very toxic; 50-500, moderately toxic; 500 up, slightly toxic.

To simplify information in this guide, the brand or trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned. This list is not complete but covers most chemicals used by potato farmers for potatoes or for other purposes.

RELATIVE TOXICITY OF PESTICIDES

The toxicity data are based on tests with rats and rabbits and are considered relevant to all mammals including humans. The principal source of information for this table is *Acute Toxicity Data for Pesticides (1970)*, R. Ben-Dyke, D.M. Sanderson and Diana N. Noakes. The following categories have been used: Dermal - LD50, 0-200, very toxic; 200 - 1,000, moderately toxic; 1,000 up, slightly toxic. Oral - LD 50, 0-50, very toxic; 50-500, moderately toxic; 500 up, slightly toxic.

To simplify information in this guide, the brand or trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

VERY TOXIC

ORAL (by mouth)	DERMAL (skin absorption)
Aqua (parathion)	Aqua (parathion)
A.W.K. (stoddard solvent. mineral oil)	Birlane (chlorfenvinphos)
Birlane (chlorfenvinphos)	Chloropicrin
Chloropicrin	Dasanit (fensulfothion)
Dasanit (fensulfothion)	Di-Syston (disulfoton)
Di-Syston (disulfoton)	Dow General (dinoseb general)
Dow General (dinoseb general)	Dow Potato Top Killer (dineb top killer)
Dow Potato Top Killer (dinoseb top killer)	Dyanap (naptalam plus dinoseb)
Dyanap (naptalam plus dinoseb)	Dyfonate (fonophos)
Dyfonate (fonophos)	MC-2 (methyl bromide plus chloropicrin)
Ethion	Metasystox R (oxydemeton-methyl)
Furadan (carbofuran)	Methyl Bromide
Gopher-Getter (milo-seed strychnine)	Monitor (methamidophos)
Gramoxone (paraquat)	Parathion
Guthion (azinphos-methyl)	Phosdrin (mevinphos)
Lannate (methomyl)	Premerge (dinoseb amine)
MC-2 (methyl bromide plus chloropicrin)	Sinox General (dinoseb general)
Methyl Bromide	Sinox PE (dinoseb amine)
Monitor (methamidophos)	Systox (demeton)
Mouse-Bait 2 (zinc phosphide)	Temik (aldicarb)
Niagara Rodent Bait (strychnine)	Totril (ioxynil)
Parathion	
Phosdrin (mevinphos)	
Premerge (dinoseb amine)	
Ramik Brown (diphacinone)	
Rozol (chlorphacinone)	
Sinox General (dinoseb general)	
Sinox PE (dinoseb amine)	
Strychnine	
Systox (demeton)	
Temik (aldicarb)	
Thiodan (endosulfan)	

MODERATELY TOXIC

ORAL (by mouth)	DERMAL (skin absorption)
2, 4-D	Cygon (dimethoate)
Bluestone (copper sulphate)	diazinon
bromoxynil	Ethion
Copper oxychloride (fixed copper)	Gramoxone (paraquat)
Cygon (dimethoate)	Guthion (azinphos-methyl)
diazinon	Lannate (methomyl)
Dibrom (naled)	Pirimor (pirimicarb)
Du-ter (fentinhydroxide)	Randox (allidochlor)
formalin (formaldehyde)	Reglone (diquat)
Lorsban (chlorpyrifos)	Rogor (dimethoate)
Metasystox R (oxydemetonmethyl)	Telone (1, 3-D)
Neutro-Cop (fixed copper)	Thiodan (endosulfan)
Pirimor (pirimicarb)	Vorlex
Reglone (diquat)	
Rogor (dimethoate)	
rotenone	
Sevin (carbaryl)	
Telone (1, 3-D)	
Toril (ioxynil)	
Tri-Cop (fixed copper)	
Vorlex	

Although the toxicity rating of Gramoxone (paraquat) has not been clearly established as "very toxic" there is no doubt that swallowing it could be fatal. There is no specific antidote for Gramoxone (paraquat). Use extreme precautions to avoid accidental swallowing of this herbicide.

SLIGHTLY TOXIC

ORAL (by mouth)	DERMAL (skin absorption)	ORAL (by mouth)	DERMAL (skin absorption)
Aatrex (atrazine)	2, 4-D	MH-30 (maleic hydrazide)	Lasso (alachlor)
Afolan (linuron)	Aatrex (atrazine)	Orthocide (captan)	Lexon (metribuzin)
Ambush (permethrin)	Afolan (linuron)	Patoran (metobromuron)	Linuron (Lorox)
Arasan (thiram)	Ambush (permethrin)	Polyram (metiram)	Lorsban (chlorpyrifos)
Basagran (bentazon)	Arasan (thiram)	Primextra (metolachlor plus atrazine)	malathion
Basamid (dazomet)	A.W.K. (stoddard solvent, mineral oil)	Princep (simazine)	Maloran (chlorbromuron)
Basfapon (dalapon)	Basagran (bentazon)	Pro Gro (carboxin)	Manzate D (maneb)
Benlate (benomyl)	Basamid (dazomet)	Pyramin (pyrazon)	Manzate 200 (mancozeb)
Bladex (cyanazine)	Basfapon (dalapon)	Randox (allidochlor)	MCPA
Botran (dichloran)	Benlate (benomyl)	Ro-Neet (cycloate)	MCPB
Bravo, Daconil (chlorothalonil)	Bladex (cyanazine)	Roundup (glyphosate)	Mesoranil (aziprotryne)
captan	Bluestone (copper sulphate)	Sencor (metribuzin)	metaldehyde
CIPC, Chloro-IPC (chlorpropham)	Botran (dichloran)	Sutan + (butylate plus inhibitor)	methoxychlor
Cythion (malathion)	Bravo, Daconil (chlorothalonil)	Tenoran (chloroxuron)	MH-30 (maleic hydrazide)
Dacthal, DCPA (chlorthal)	bromoxynil	thiram	Neutro-Cop (fixed copper)
Difolatan (captafol)	captan	Thuricide (Bacillus thuringiensis)	orthocide (captan)
Dipel (Bacillus thuringiensis)	CIPC, Chloro-IPC (chlorpropham)	Treflan (trifluralin)	patoran (metobromuron)
Dithane M-22, Dithane M-45 (maneb, mancozeb)	copper, fixed	Tropotox (MCPB)	Polyram (metiram)
Dithane Z-78 (zineb)	Cythion (malathion)	Vapam (metam, SMDC)	Primextra (metolachlor plus atrazine)
Dowpon (dalapon)	Dacthal, DCPA (chlorthal)	Vegiben (chloramben)	Princep (simazine)
Dymid, Enide (diphenamid)	Dibrom (naled)	zineb	Pro Gro (carboxin)
Dyrene (anilazine)	Difolatan (captafol)	ziram	rotenone
Easout (thiophanate-methyl)	Dipel (Bacillus thuringiensis)		Ro-Neet (cycloate)
Eptam (EPTC)	Dithane M-22, Dithane M-45 (maneb, mancozeb)		Roundup (glyphosate)
Eradicane (EPTC plus inhibitor)	Dithane Z-78 (zineb)		Sencor (metribuzin)
ferbam	Dowpon (dalapon)		Sevin (carbaryl)
Gesagard (prometryne)	Du-ter (fentinhydroxide)		Sutan + (butylate plus inhibitor)
Hoe-Grass (dichlofop-methyl)	Dymid, Enide (diphenamid)		Tenoran (chloroxuron)
Kelthane (dicofol)	Dyrene (anilazine)		thiram
Lasso (alachlor)	Easout (thiophanate-methyl)		Thuricide (Bacillus thuringiensis)
Lexon (metribuzin)	Eptam (EPTC)		Treflan (trifluralin)
Linuron (Lorox)	Eradicane (EPTC plus inhibitor)		Tri-Cop (fixed copper)
malathion	ferbam		Tropotox (MCPB)
Maloran (chlorbromuron)	Furadan (carbofuran)		Vapam (SMDC, metam)
Manzate D (maneb)	Gesagard (prometryne)		Vegiben (chloramben)
Manzate 200 (mancozeb)	Hoe-Grass (dichlofop-methyl)		zineb
MCPA	Kelthane (dicofol)		ziram
MCPB			
Mesoranil (aziprotryne)			
metaldehyde			
methoxychlor			

LIST OF PESTICIDE COMMON NAMES AND THEIR PRODUCT TRADE NAMES

Trade names are capitalized and common names are not capitalized.

FUNGICIDES

		Chemical Classification
anilazine	Dyrene	M
Arasan	thiram	C
Benlate	benomyl, Tersan 1991	M
benomyl	Benlate, Tersan 1991	M
Botran	dichloran	OH
Bravo	chlorothalonil	OC
captafol	Difolatan	M
captan	Captan Orthocide	M
carbathiin/thiram	Pro Gro	M
chloropicrin	Chloropicrin, Larvacide	OC
chlorothalonil	Bravo, Daconil, Termil	OC
copper oxychloride	fixed copper	I
Daconil	chlorothalonil	OC
dichloran	Botran	OH
Difolatan	captafol	M
dinocap	Karathane	N
Dithane M-22	maneb	D
Dithane M-45	mancozeb	D
Dithane Z-78	zineb	D
Du-ter	fentin-hydroxide	M
Dyrene	anilazine	M
Easout	thiophanate-methyl	M
ferbam	Fermate	D
Fermate	ferbam	D
fixed copper	copper oxychloride, Neutro-Cop, Tri Cop	I
formaldehyde *	Formalin *	M
Karathane	dinocap	N
mancozeb	Dithane M-45, Manzate 200	D
maneb	Mantox, Dithane M-22, Manzate D	D
Mantox	maneb	D
Manzate D	maneb	D
Manzate 200	mancozeb	D
Mertect	thiobendazole	M
Dowfume MC-2*	methyl bromide *	OH
metalaxyl	Ridomil	
metam, sodium	Vapam, VPM	C
methyl bromide *	Dowfume MC-2*	OH
metiram	Polyram	D
Neutro-Cop	fixed copper	I
Orthocide	captan	N
Polyram	metiram	D
Pro Go	carbathiin/thiram	M
Ridomil	metalaxyl	
Termil	chlorothalonil	OC
Tersan 1991	Benlate, benomyl	M
thiobendazole	Mertect	M
thiophanate-methyl	Easout	M
thiram	Thiram, Arasan	C
Tri-Cop	fixed copper	I
Vapam	metam, sodium	D
vorlex	Vorlex	M
VPM	metam, sodium	D
zineb	Dithane Z-78	D

TOP-KILLERS

diquat	Reglone	M
dinoseb *	Sinox General *, Dow Top-Killer *	N
Dow Top-Killer *	dinoseb *	N
Reglone	diquat	M
Sinox General *	dinoseb *	N

* Caution very toxic.

SPROUT INHIBITORS

CIPC	Sprout Nip	M
maleic hydrazide	MH-30	M
MH-30	maleic hydrazide	M
Sprout Nip	CIPC	M

HERBICIDES

Aatrex	atrazine	T
Afolan	linuron	U
Agricultural Weedkiller No. 1 *	stoddard solvent *	M
alachlor	Lasso	M
allidochlor	Randox	M
Amitrol	amitrole	
Amiben	chloramben	
atrazine	Aatrex	T
Basagran	bentazon	M
Basfapon	dalapon	M
bentazon	Basagran	M
Bladex	cyanazine	T
Brominal	bromoxynil	OC
Brominal M	bromoxynil * CPA	OC
bromoxynil	Torch, Pardner	OC
bromoxynil/MCPA 1:1	Brominal M, Sabre, Buctril M	OC
Buctril M	bromoxynil/MCPA	OC
butylate	Sutan	C
CDAA (allidochlor)	Randox	C
CIPC	chlorpropham	M
chloramben	Amiben	

* Caution, very toxic.

Chloro-IPC	chlorpropham	M
chloroxuron	Tenoran	U
chlorpropham	Chloro-IPC, CIPC	C
cyanazine	Bladex	T
cycloate	Ro-Neet	
Dacthal	DCPA (chlorthal)	M
dalapon	Basfapon, Dowpon	M
DCPA (chlorthal)	Dacthal	M
dichlofop-methyl	Hoe-Grass	
diphenamid	Dymid, Enide	M
diquat	Reglone	M
DNBP (dinoseb) *	Dow General *, Sinox General *	N
DNBP (dinoseb amine) *	Premerge, Sinox PE *	N
Dow General *	DNBP (dinoseb) *	N
Dowpon	dalapon	M
Dyanap	dinoseb + naptalam	
Dymid	diphenamid	M
Enide	diphenamid	M
Eptam	EPTC	C
EPTC	Eptam	C
Eradicane	EPTC + R25788	C
Fusilade	fluazifop-butyl	M
glyphosate	Roundup	M
Hoe-Grass	dichlofop-methyl	
Gramoxone *	paraquat *	M
ioxynil *	Totril *	M
Lasso	alachlor	M
Lexone	metribuzin	T
linuron	Afalon, Linuron Lorox	U
Lorox	linuron	U
MCPA	MCP Amine	OC
MCP Amine	MCPA	OC
MCPB	Tropotox	OC
MCPB:MCPA/15:1	Tropotox Plus	OC
Metolachlor + atrazine	Primextra	M
metobromuron	Patoran	U
metribuzin	Lexone, Sencor	T
naptalam + dinoseb	Dyanap	
paraquat *	Gramoxone *	M
Pardner	bromoxynil	OC
Patoran	metobromuron	U
Poast	sethoxydim	M
Premerge *	DNBP (dinoseb amine) *	N
Primextra	metolachlor + atrazine	M
Princep	simazine	T
Pyramin	pyrazon	M
pyrazon	Pyramin	M
Randox	CDAA (allidochlor)	M
Reglone	diquat	M
Ro-Neet	cycloate	
Roundup	glyphosate	M
Sencor	metribuzin	T
sethoxydim	Poast	M
simazine	Princep	T
Sinox General *	DNBP (dinoseb) *	N
Sinox PE *	DNBP (dinoseb amine) *	N
stoddard solvent *	Agricultural Weed Killer No. 1 *	M
Surpass	vernolate	
Sutan	butylate	C
Tenoran	chloroxuron	U
Terraklene	paraquat + simazine	
Torch	bromoxynil	OC
Totril *	ioxynil *	M
Treflan	trifluralin	N
trifluralin	Treflan	N
Tropotox	MCPB	OC
Tropotox Plus	MCPB:MCPA/15:1	OC
vernolate	Surpass	

NEMATICIDES

Basamid	dazomet	M
dazomet	Basamid	M
Dowfume *	methyl bromide *	OH
methyl bromide *	Methyl Bromide *, Dowfume MC-2*	OH
1,3-D	Telone	OC
vorlex	Vorlex	M

RODENTICIDES

chlorphacinone *	Rozol *	
diphacinone *	Ramik Brown *	M
Gopher Getter *	strychnine *	M
Mouse-Bait 2*	zinc phosphide *	I
Niagara Rodent Bait *	strychnine *	
Ramik Brown *	diphacinone *	M
Rozol *	chlorphacinone *	
strychnine *	Gopher Getter *, Niagara Rodent Bait *	M
zinc phosphide *	Mouse-Bait 2*	I

* Caution, very toxic.

INSECTICIDES

		Chemical Classification	Mode of Action
aldicarb *	Temik *	C	Sy
Ambush	permethrin	M	C, S
Aqua *	parathion *	OP	C, S
azinphosmethyl *	Guthion *	OP	C, S
Bacillus thuringiensis	Thuricide, Dipel	M	S
Basudin	diazinon	OP	C, S
Belmark	fenvalerate	M	C, S
Birlane *	chlorfenvinphos *	OP	C
carbaryl	Sevin	C	C, S
carbofuran *	Furadan *	C	C, S, Sy
chlorfenvinphos *	Birlane *	OP	C
chlorpyrifos	Dursban, Lorsban	OP	C, S
Cygon	dimethoate	OP	C, S, Sy
Dasanit *	fensulfothion *	OP	C
Decis	deltamethrin	M	C, S
deltamethrin	Decis	M	C, S
demeton *	Systox *	OP	C, Sy
diazinon	Basudin	OP	C, S
Dibrom	naled	OP	C, S
Dipel	Bacillus thuringiensis	M	S
dimethoate	Cygon, Sys-Tem, Lagon	OP	C, S, Sy
disulfoton *	Di-Syston *	OP	Sy
Di-Syston *	disulfoton *	OP	Sy
Dursban	chlorpyrifos	OP	C
Dyfonate *	fonofos *	OP	C
Dylox	tirchlorfon	OP	C, S
endosulfan *	Thiodan *	OC	C, S
ethion *	Ethion *	OP	C, S
fensulfothion *	Dasanit *	OP	C
fenvalerate	Belmark	M	C, S
fonofos *	Dyfonate *	OP	C, S
Furadan *	carbofuran *	C	C, S, Sy
Guthion *	azinphosmethyl *	OP	C, S
Imidan	phosmet	OP	C
Lannate *	methomyl *	C	C, S, Sy
Lindane	lindane	OC	S, F, C
Lorsban	chlorpyrifos	OP	C, S
malathion	Malathion	OP	C, S
Marlate	methoxychlor	OC	C, S
Metasystox R *	oxydemeton-methyl *	OP	C, Sy
Methamidophos *	Monitor *	OP	C, S, Sy
methidathion	Supracide	OP	C, S
methomyl *	Lannate*	C	C, S, Sy
methoxychlor	Marlate	OC	C, S
mevinphos *	Phosdrin *	OP	C, Sy
Monitor *	methamidophos *	OP	C, S, Sy
naled	Dibrom	OP	C, S
oxamyl	Vydate	C	C, Sy
oxdemeton-methyl *	Metasystox R *	OP	C, Sy
parathion *	Parathion*	OP	C, S
permethrin	Pounce, Ambush	M	C, S
Phosdrin *	mevinphos *	OP	C, Sy
phosmer	Imidan	OP	C

* Caution, very toxic.

pirimicarb	Pirimor	C	C, F
Pirimor	pirimicarb	C	C, F
Pounce	permethrin	M	C, S
rotenone	Rotenone	M	C, S
Sevin	carbaryl	C	C, S
Supracide	methidathion	OP	
Sys-Tem	dimethoate	OP	
Systox *	demeton *	OP	C, Sy
Temik *	adlicarb *	C	Sy
Thimet *	phorale *	OP	C, Sy, F
Thiodan *	endosulfan *	OC	C, S
Thuricide	Bacillus thuringiensis	M	S
Trichlorfon	Dylox	OP	C, S
Vydate	oxamyl	C	C, Sy

MITICIDES

dicofol	Kelthane	OC	C
Kelthane	dicofol	OC	C

MOLLUSCICIDES

metaldehyde	Slug Bait	M	S
methiocarb	Mesuro	C	C, S

The class of chemical to which a pesticide belongs and its mode of action is designated as follows:

Chemical Classification

- C carbamate
- I inorganic
- OP organophosphate
- D dithiocarbamate
- OC organochlorine
- OH organohalogen
- N dinitro
- T triazine
- U methyl urea
- M miscellaneous
- ☠ designates a very toxic pesticide

Mode of Action

- C contact
- S stomach
- Sy systemic
- F fumigant

DISEASE MANAGEMENT

INTRODUCTION

The potato plant is susceptible to a wide variety of diseases that can severely reduce yield and quality of tubers. These diseases are caused by infectious bacteria, fungi, viruses and mycoplasma-like organisms that must be kept to a minimum from year to year if a grower is to maintain a profitable and quality operation. Adverse environmental conditions can also cause a number of noninfectious potato diseases. Diseases occur on plants in the field, as well as in tubers in storage. In general, most infectious potato diseases can be managed by using certified seed, following proper sanitary measures when handling seed or tubers, and through the use of pesticides. The following are the most serious diseases of potatoes in Alberta. For further information, obtain a copy of "Diseases of Potatoes in Alberta", AHRC pamphlet 86-14 from the Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta, T0J 0J0. Table 9 is a list of disease control chemicals for potatoes.

BACTERIAL DISEASES

Bacterial Ring Rot. Bacterial ring rot is a highly infectious disease caused by the bacterium *Corynebacterium sepedonicum*. It has caused serious losses in Alberta in the past and is named as a pest in The Agricultural Pests Act of Alberta. Any person who plants 0.5 ha (1 ac) or more of potatoes that are intended for sale must obtain a licence from the Alberta Potato Commission. Such fields will be inspected for bacterial ring rot. If the disease is detected, the owner of the infested potatoes will be ordered to comply with the regulations set out in the Agricultural Pests Act.

Foliar symptoms of the disease vary with the variety of potato grown and stage of the growing season. In all varieties and in advanced stages of development, the lower stem of infected plants will exude a milky ooze when cut and squeezed. A cheesy cream-colored liquid oozes from the vascular system when an infected tuber is cut and squeezed.

During seed cutting, bacteria from infected tubers are smeared on the cutting knives and on other equipment. Healthy seed pieces can become infected when they come in contact with these contaminated surfaces. Ring rot bacteria can survive for five years in dried potato stems and for two years on dry burlap, plastic or plywood surfaces. The bacteria can live for at least eight months after being subjected to temperatures of -5°C to -40°C and therefore are not necessarily killed in debris left in the field or in opened and unheated storages.

Bacterial ring rot is controlled by the following methods:

- Use certified seed.
- Thoroughly clean and disinfest equipment, tools, trucks and storages (see seed potato section).
- Dispose of any crop that is found to have ring rot and do not use it for seed.
- Sprout inhibit infested potatoes before March 1.
- Practise crop rotation, and do not plant potatoes after potatoes.
- Allow potato debris that is infested with BRR to disintegrate before replanting potatoes.
- Dispose of all used sacks.

Bacterial Soft Rot. Bacterial soft rot is a common and often serious storage disease of potatoes. It is caused by the bacterium *Erwinia carotovora* var. *carotovora* and certain other species of soil- and tuber-borne bacteria. Tuber tissue infected with soft rot bacteria is at first cream-colored, but later oozes a foul smelling, slimy mass of bacteria and decomposed potato tissue. Bacterial soft rot may follow freezing injury or rough handling that cause excessive bruising. It also can cause rot on tubers that are wet. Bacterial soft rot is controlled by the following methods.

- Minimize mechanical damage to tubers during harvesting, handling, and packing operations.
- Use clean water during washing operations. It should be changed often or chlorinated.
- Remove potato cull piles, discarded vegetables and plant refuse from fields and storages.
- Control of other tuber disease helps in the reduction of bacterial soft rot.
- Prevent condensation water from forming on tubers by ensuring that cold tubers are ventilated with cool air (See storage section).

Blackleg. Blackleg is a common disease of potato plants caused by the bacterium *Erwinia carotovora* var. *atroseptica*. Symptoms of the disease include stunting, yellowing of leaves, leafrolling, and slimy black appearance of the lower stem. A tuber rot similar to bacterial soft rot may also develop. Blackleg bacteria overwinter in the soil and on tubers. The primary source of the disease is the planting of infested seed potatoes. Blackleg is controlled by the following methods.

- Use certified seed which is blackleg free.
- Clean and disinfest seed cutters, handling equipment, and trucks frequently.
- Avoid planting in cold wet soils.
- Avoid bruising during planting, cultivating, roguing and harvesting.
- Rogue diseased potato plants to avoid spread to neighboring plants.

Common Scab. Common scab is a bacterial disease caused by *Streptomyces scabies*. The scab organism occurs naturally in the soil where it lives on plant debris. Symptoms of potato scab occur on the tubers as scab-like areas that vary in their size and dimensions.

Although scab does not affect yield of potatoes, severely infected tubers affect visual quality. Deep scabs may

require extra deep peeling by consumers and processors. Common scab is controlled by the following methods.

- Plant scab-free or treated seed on land free from scab.
- Use a crop rotation of 3-4 years, preferably with legumes.
- Green manure to inhibit the scab organism.
- Avoid alkaline soil amendments such as lime, ashes or manure.
- Treat seed tubers with Polyram, captan, or formaldehyde.
- Plant moderately resistant cultivars such as Russet Burbank, Norgold Russet, Norchip, Norland and Superior.

* Formaldehyde may damage seed pieces if the exposure period is longer or the concentration higher than recommended.

FUNGAL DISEASES

Early Blight. Early blight is an infectious foliar disease of potato plants caused by the fungus *Alternaria solani*. Leaves of infected plants have brown to black spots made up of concentric rings that produce a "target board" effect. The spots increase in size and eventually the entire leaf may die. The fungus overwinters in dead vines and leaves, and refuse. High humidity or water on the leaf surface is necessary for infection.

Early blight is controlled by the following methods:

- Rotate potatoes at least every two years preferably with small grains.
- Plow down or destroy all refuse.
- Plant disease-free seed.
- Irrigate according to soil moisture requirements of the crop.
- Allow tubers to mature in the ground before harvesting.
- Use foliar sprays of Dyrene (WP) (anilazine); Difolatan (SU) (captafol); Bravo (SU,WP) (chlorothalonil); Dithane M-45, Manzate 200 (DU,WP) (mancozeb); Dithane M-22 (DU,WP) (maneb); Chem-cop 53 (WP) (tribasic copper sulphate); Zineb (DU, WP).

Start chemical control when most of the lower leaflets (next to the ground) contain one or more spots. Treat the field after sprinkling when the soil has dried sufficiently to allow equipment to go through. Continue application after each irrigation until conditions for disease development no longer exist or the recommended preharvest interval is reached.

Rhizoctonia disease. There are two distinct forms of disease caused by the fungus *Rhizoctonia solani*. One that attacks the plant and the other the tubers. Typical symptoms on the plant include aerial tubers, pale green leaves, leafroll, purpling of the upper surface of the leaves, brown cankers on stolons and roots and white felt-like covering on lower stems. Black scurf, which consists of small hard black patches, appears on tubers. The fungus is soil-borne and can live on soil debris and other plants.

Rhizoctonia is controlled by the following methods.

- Practise a four year crop rotation with cereal or forage crops. Avoid planting potatoes after sugar beets or legume crops.
- Plant in warm well-drained soil.
- Do not over-irrigate.
- Cover seed pieces with 5-7 cm of soil and hill potatoes after they have emerged.
- Maintain recommended nutrient levels.
- Control weeds.
- Treat seed pieces with captan (WP); and treat potatoes going into storage with Mertect (SN,WP) (thiabendazole), or soak whole tubers in formaldehyde (SN)*.
- Use seed that is free of black scurf.

* Formaldehyde may damage tubers if the exposure period is longer and the concentration higher than is recommended.

Seed-Piece Decay. Various species of soil and seed-borne fungi and bacteria are known to cause seed-piece decay. Seed-pieces may exhibit a dry rot or soft rot decay depending upon the microorganisms involved. Decay can be aggravated by insect injury, freezing, low soil temperatures, excess soil water or fertilizer and improper use of seed treatments. The microorganisms that cause seed-piece decay usually enter through wounds.

Decay is controlled by the following methods:

- Cut, treat, and plant seed potatoes the same day. If this is not possible, maintain cut seed at 10°C - 15°C with a high relative humidity to promote rapid healing.
- Protect cut seed from the hot sun or a drying wind.
- Plant whole seed.
- Dust seed with captan (WP), Dithane M-45, Manzate 200, (mancozeb) (WP); Polyram (DU) (metiram); or Easout (WP) (thiophanate-methyl) prior to planting.
- Plant in warm moist soil to promote wound healing and rapid sprout growth.

Leak. Leak is a storage disease of potato tubers caused by the fungus *Pythium ultimum*. Flesh of infected tubers is granular, very watery, and may range from cream-colored to shades of black. Water may drip freely from tubers in the early stages of decay, especially if they are stored or shipped at high temperatures. The fungus is present in many soils and attacks the roots of many different plants. The fungus overwinters in plant debris particularly in wet soils.

Leak is controlled by the following methods:

- Grow potatoes on well-drained soils.
- Harvest when tubers are mature in cool weather.
- Keep harvested tubers dry and storing promptly after digging. Store at recommended temperatures and humidity.
- Cool tubers harvested in hot sunny weather to below 10°C and market immediately.

Dry Rot. Dry rot is a common storage disease of potato tubers caused by several different species of the *Fusarium* fungus. The disease usually results in a serious decay of internal tissue. Depending upon the variety of potato, the diseased tissue may be light brown to black and dry to slightly moist and cheesy. Cavities are often formed within the tuber. The fungi that cause dry rot are present in soils.

The amount of decay in storage depends upon the amount of fungus in the soil, the amount of mechanical damage done to the tubers during digging and harvesting, and on the susceptibility of the potato variety.

Dry rot is controlled by the following methods:
- Treat seed pieces with one of the following fungicides prior to planting: captan (WP); Polyram (DU) (metriam); (WP) Manzate 200, Dithane M-45 Agrox (mancozeb); Easout (WP) (thiophanate-methyl).
- Handle treated seed with clean, disinfested equipment.
- Harvest during cool dry weather.
- Avoid bruising during harvesting, handling and grading operations.
- Spray tubers with Mertect (thiabendazole) as they go into storage.

Fusarium and Verticillium Wilts: Wilt diseases caused by *Fusarium* spp. and *Verticillium* spp. are becoming increasingly important in seed potato production in Alberta. Plants infected with wilts start to show symptoms in the middle of the growing season. Individual leaves become pale green or yellow and the entire plant wilts and dies prematurely. The lower stems of diseased plants and tubers have brown discoloration in the vascular tissue when cut open. Both *Fusarium* spp. and *Verticillium* spp. are soil-borne fungi and, once established, can live for long periods of time in the soil even if the host potato crop has not been planted for many years. The disease can become established through the use of infected seed.

Wilts are controlled by the following methods:
- Avoid wounding and bruising at harvest.
- Treat seed with chemicals recommended for seed-piece decay.
- Do not use tubers taken from wilted plants for seed.
- Avoid contaminating clean fields with soil from diseased fields, diseased tubers or plant refuse.

VIRUS DISEASES

The following diseases are especially important in seed potato production.

Potato Leaf Roll. The most important viral disease of potato plants in Alberta is potato leaf roll. The virus which causes the disease is spread by aphids, primarily the green peach aphid, however, it can also spread by infected seed tubers. Leaf roll symptoms vary depending upon the stage of infection. Plants from infected seed tubers are stunted, have a pale green color, stiff uprolled leaves, and sometimes purple tinted leaves. Tubers from plants infected in the current season develop fine lines of discoloration in the tuber.

Leaf roll is controlled by the following methods:
- Use only certified seed, that is free of leaf roll.
- Control volunteer potatoes if they occur.
- Control aphids if they are present.

Spindle Tuber. Spindle tuber is a serious disease of seed potatoes and is caused by the spindle tuber viroid. Plants infected with spindle tuber viroid are upright, dwarfed and much thinner than normal vines. The stems are often more branched and branches form very sharp angles where joined to the stem. Affected tubers are dwarfed and are usually narrow and spindle-shaped. Eyes are numerous and the tubers are often cracked. Spindle tuber is spread by insects such as aphids, grasshoppers, Colorado potato beetles, and flea beetles, as well as seed cutting knives, planters and infected seed.

Spindle tuber is controlled by the following methods:
- Use disease-free stock for seed.
- Control insects.
- Rogue diseased plants, ensuring that the entire plant is removed.
- Plant whole seed and avoiding leaf contact by people and equipment during field operations.
- Decontaminate knives and other equipment frequently with detergents, household bleach or quartenary ammonia compounds.

Mosaic. The mosaic diseases are a group of three forms called simple, mild and rugose mosaics. This disease is caused by potato viruses A, X, S, and Y. Each form of mosaic is caused by a different virus or combination of viruses. Symptoms of mosaic include a yellow green mottling of the leaves, and leaves that may be wrinkled, distorted or reduced in size. Mosaic viruses can be spread by insects, infected seed-pieces, cutting knives, and by contact with infected plants.

Control mosaic by the following methods:
- Plant virus-free stock.
- Control insects, especially aphids.
- Rogue plants with obvious mosaic, including seed-pieces, as soon as they are detected.
- Avoid rubbing potato foliage with clothing and machinery.
- Disinfest cutting knives and equipment as often as possible. Use household bleach, soapy water or quartenary ammonia compounds.

Witches' Broom. Witches' broom of potatoes is caused by a mycoplasma-like organism. Infected plants are dwarfed, leaves are a lighter green than normal, and the leaf margins are reddish-yellow. The buds at the junctions of the main stem grow along with the branches and as a result the plant becomes bushy. Plants from infected seed have many shoots. Stolons of infected plants are long and abnormally white, with chains of small tubers. The disease

is spread through infected tubers; however, in Western Canada, two species of leafhoppers have been observed to transmit the disease from clover to alfalfa to potato.

Control witches' broom by the following methods:

- Plant disease-free seed.
- Eliminate from planting stocks all tubers that have premature sprouts, especially hair-like ones.
- Rogue infected plants.
- Control leafhoppers, if practical.

ENVIRONMENTAL DISEASES

Blackheart. Blackheart of potatoes results from a poor oxygen supply to the tuber. The internal tuber tissue shows an irregular blue-black discoloration in the central portion of the tuber. Blackheart is prevented by ventilation and by storing at recommended temperatures.

Low Temperature Injury. Low temperature or freezing injury can occur to potatoes that are exposed to a heavy frost in the soil or to tubers that have been excessively chilled in a storage bin. Tubers may be frozen or exhibit chilling injury. Frozen tissue upon thawing discolors and breaks down into a soft watery mass. Chilling injury often results in streaks of discoloration in the vascular tissue of the tuber. Frozen or chilled potatoes should not be used for seed as cut surfaces may not heal.

Low temperature injury can be reduced or prevented by the following:

- Store at temperatures above 3.0°C.
- Ventilate frosted tubers in storage.
- Cull out frozen potatoes prior to storage. Re-grading of frozen potatoes may be necessary after some period in storage.

Table 9. Disease Control Chemicals*.

Product	Rate	Dry Rot	Early Blight	Rhizoctonia Disease	Scab	Seed Piece Decay
Captan	2.5-35 kg/1000 L (Dip)	+		+	+	+
Difolatan	1.8-3.8 L/ha 1.8-3.8 L/ac		+			
Dithane M-22	1.7 - 2.2 kg/ha 0.7 - 0.9 kg/acre		+			
Dithane M-45	1.7 - 2.2 kg/ha 0.7 - 0.9 kg/ac	+	+			0.5 kg/100 kg seed
Easout	0.5 kg/100 kg seed	+				
Manzate 200		+	0.4-13 kg/ac 1.1-3.3 kg/ha			+ 1 kg/100 kg seed
Polyram	1.5 kg/100 kg seed	+			+	+
Tribasic Copper Sulphide	5 kg/1000 L sprayed/ha 2 kg/400 L sprayed/ac		+			
Zineb 75-W	2.3 - 3.4 kg/h 0.9-1.4 kg/ac		+			
Mertect	8 L in 170 L water at 2 L/tonne of seed			+		
Dyrene (Anilazine)	2.2 - 6.5 kg/ha 0.9 - 2.6 kg/ac		+			
Bravo	1.6 - 2.4 L/ha 0.6 - 1.00 L/ac		+			
Formaldehyde**				+	+	

* Producers are reminded to check current product labels for application rates, timing, water and pressure recommendations. Application procedures are not listed here because of the wide variation of methods. Rates are supplied as an ordering guide only.

** Cold treatment - Soak uncut tubers in a solution of 4.5 ml of 37% formaldehyde/L of water for 2 hours.
Hot treatment - Soak uncut tubers in a warm (48-52°C) solution of 9.0 ml of 37% formaldehyde/L of water for 3-4 minutes, cover for one hour and dry before cutting and planting.

Hollow Heart. Hollow heart is a disorder that has been associated with excessively rapid tuber growth. The disorder is primarily found in large tubers where a cavity is formed in the center of the tuber. The cavity may have a variety of shapes and the walls of the cavities are white to light brown in color and no rot is present. The disorder is important because affected tubers show no external symptoms and so cannot be graded out. It is thought that hollow heart is promoted when growing conditions that cause rapid tuber enlargement are present.

Control hollow heart by the following:

- Use closer spacings of cultivars known to get larger. The increased competition between plants should prevent excessively large tubers.
- Maintain uniform soil moisture.
- Avoid missing hills when planting.

Malformed Tubers. Growth irregularities such as secondary growth and growth cracks are common disorders of potatoes.

Secondary growth such as knobbiness or secondary tubers have been attributed to temperature extremes in the field. However, other conditions such as nutrient and water imbalances have been implicated in irregular tuber development.

Growth cracks may arise from rapid tuber growth and are often the result of improper fertilizer placement.

Reduce or prevent malformed tubers by the following:

- Maintaining uniform soil moisture, particularly during tuber development.
- Following recommended fertilizer rates and application.

INSECT MANAGEMENT

Insects can cause serious yield losses in potatoes by feeding on and destroying the leaves, stems or tubers. In addition, insects such as aphids and leafhopper can cause indirect losses by acting as vectors for a variety of pathogens that cause plant diseases. Therefore effective insect control is an essential part of any profitable potato production program. Knowledge of insects and the damage they cause is important.

Weather is one of the most important factors influencing the size of insect populations. Thus, a cold winter with much snow favors the survival of insects wintering in plant debris, such as the tuber flea beetle. However, an open winter with little snow and fluctuating temperatures reduces the number of insects emerging in the spring. Similarly, warm dry weather promotes the build up of insect populations, while cool wet weather kills many young insects as they hatch from the eggs.

Effective insect control depends on a combination of cultural and chemical practices. For example, sanitation such as the removal of plant debris after harvest will eliminate the conditions required by a number of insect species to overwinter successfully. In addition to reducing competition with the crop, good weed control in and around the potato fields removes alternate food sources for many of the pest insects, particularly early in the spring, before the crops have emerged from the ground.

For the foreseeable future, the use of insecticides will remain the mainstay of any insect control program in potatoes. Since no single insecticide will control all potato insects, it is necessary to become familiar with the potato pests and their various stages, and to monitor the fields carefully, so that application of the appropriate pesticide can be timed for maximum effectiveness.

Some insects, such as the Colorado potato beetle, readily develop resistance to a variety of insecticides. It is therefore important to avoid reliance on only one or two of the chemicals recommended. Alternating the use of several insecticides, particularly those of different chemical groups, such as carbamates and organophosphates, will impede the development of resistance and increase effectiveness of the sprays applied. Application of lower dosages than recommended may allow the target insect to develop resistance more quickly, whereas higher doses are likely to damage the crop as well as the environment.

APHIDS

Aphids are small soft-bodied insects that may be found on potatoes any time after mid-June. In feeding on the sap of the potato plants, these insects are able to transmit a variety of plant viruses. Aphids normally produce live young and under hot and dry weather conditions reproduce rapidly and are capable of developing huge populations in a very short time. Although aphids are normally wingless, winged forms generally appear when environmental conditions deteriorate. The winged aphids fly to other plants and frequently transfer the pathogen to their new host.

Potato Aphids (PA). Of the two aphid species found in potato fields in Alberta, the potato aphid is the more numerous. This aphid is the largest of the aphids that may attack potatoes. Usually green in color, individuals of this species may be red, brown, yellow, orange, or even purple. These aphids are usually found on the underside of leaves. This species can transfer the viruses causing mild mosaic and rugose mosaic. It is a poor vector of leaf roll virus; however, since the green peach aphid, discussed below, is a very effective vector of leaf roll, growers should be able to distinguish the two or control measures must be taken. In addition to virus spread, a toxin produced by the insects is injected during the feeding process and may cause mottling, curling, premature death of the leaflets. Large quantities of honey dew excreted by the insects may cause the tops of the plants to become sticky if populations are extreme.

Potato aphids overwinter in the egg stage on rose bushes.

Wingless females hatch from these, and produce living young females, some of which develop wings and fly to new hosts. The potato aphid feeds on over 30 different plant species, including members of the nightshade family of which potatoes are a member. There are several generations of winged and wingless forms during the summer. Both winged males and females appear during late summer and early fall. These fly to rose bushes where the females give birth to wingless females, that mate with the winged males and produce the winter eggs (Figure 9).

Green Peach Aphids (GPA). The green peach aphid is a highly efficient vector of the potato leaf roll virus.

This species also injects a toxin during the feeding process which may cause curling, mottling, wrinkling and streaking; premature death of leaflets, and even of entire plants may occur in dry years.

It is believed that the GPA does not overwinter outdoors in Alberta. Populations are maintained from year-to-year by overwintering primarily in greenhouses; however, some do survive in home root cellars. In the spring winged females fly to weeds and are carried outside with bedding plants. They multiply rapidly for several weeks and by July they move to potatoes and fly from field to field, transmitting the viruses to previously healthy plants.

Winged females usually appear in the fall and some of these are successful in becoming established in commercial greenhouses. (Figure 10).

MONITORING APHID NUMBERS

Seed growers must control problem populations of aphids to maintain seed quality. The amount of potato leaf roll virus (PLRV) that spreads in a field will be directly proportional to the level of aphid vectors present in a field. It is therefore important to estimate aphid populations using a leaf-count sampling system, so that the potential for leaf roll spread can be determined. To assist growers with monitoring and recording, two aphid charts are available from the Alberta Seed Potato Program, Box 10, Olds, Alberta, T0M 0P0. These charts provide growers with information on when and how often monitoring should be done, and when control procedures should be started.

Aphid monitoring should begin in early July. If growers follow the sampling procedure suggested in the aphid monitoring charts, each field will be divided into four plots. Following a predetermined sampling plan that provides for representative samples, a total of 25 leaves are taken from each of the four plots. A single leaf is removed from the lower one half of each plant sampled.

The potato aphids and green peach aphids are counted on each compound leaf sampled. As identification of aphids is difficult when they are young it is necessary to use a ten powered magnifying lens. The large body size and elongated shape of the potato aphid distinguish it from the smaller oval-bodied green peach aphid. However, identification of young aphids can be difficult and growers may wish assistance. (See back cover).

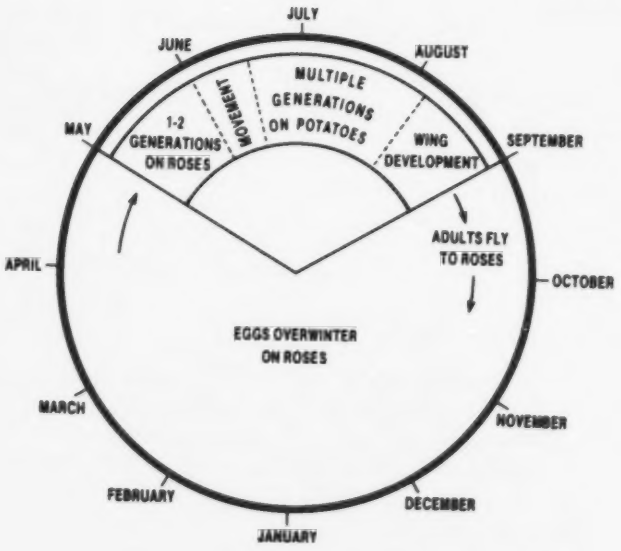


Figure 9. Annual Cycle of the Potato Aphid.

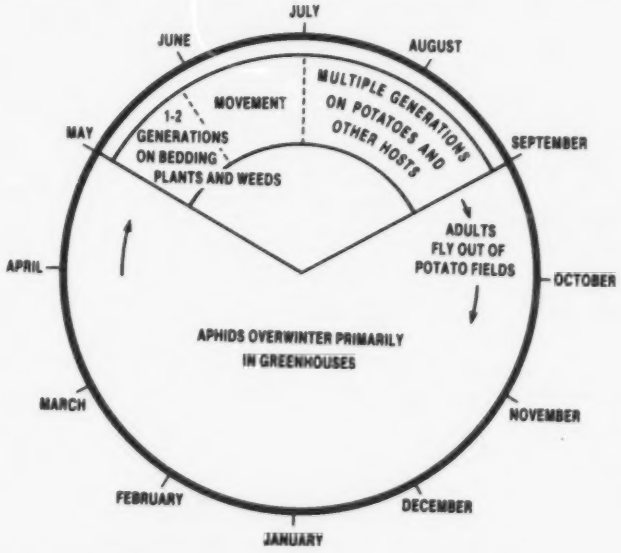


Figure 10. Annual Cycle of the Green Peach Aphid.

Economic Threshold. The number of aphids is then totalled and compared with the economic threshold for that field. The economic threshold of a field is the population level of an insect at which the benefits of control exceed the costs of control. The economic threshold for GPA is based on the number of aphids per 100 leaves. The level of potato leaf roll virus in the field, and the nearness to other sources of aphids and PLRV affect the threshold level. Use the following procedure to determine the economic threshold of GPA's or for a field.

The total points represents the number of GPA per 100 compound leaves and indicates when control should take place.

Level of PLRV in the field.

0	10 points	
trace	5 points	
moderate	2 points	_____ points

Distance to other potato fields, greenhouses, nurseries, or market gardens.

close	0 points	
far	5 points	_____ points

Total _____

For example, a field with a trace of PLRV (5) and close to other potato fields or greenhouse (0), has an economic threshold of 5. If more than 5 green peach aphids are found on 100 compound leaves then control should be used. The threshold for the potato aphid is 30 times that for GPA. In the above example the PA threshold is 150 aphids per 100 leaves.

Aphid Control. The following insecticides have been found to be effective for aphid control in Alberta.

Temik 10G (aldicarb) at 11 kg/ha (4.5 kg/ac). Temik is a granular compound applied at planting time. It must not be applied to potatoes to be harvested within 90 days of planting.

Pirimor 50WP (pirimicarb) at 425 to 550 g/ha in 500 to 1000 L of water (170-220 g/ac in 200 to 400 L water). (7 days).

Belmark 30EC (fenvalerate) at 225 to 325 mL/ha in 450 to 550 L of water (90-130 mL/ac in 180 to 220 L of water). (7 days).

Thimet 15G (phorate) at 15-22 kg/ha. (6-9 kg/ac).

Thiodan 40EC (endosulfan) at 1.5 L/ha in 450-550 L of water (600 mL/ac in 180-220 L of water). The 50 WP formulation can be used at 1.5 kg/ha (0.4 kg/ac). (1 day).

Monitor 48SN (methamidophos) at 1.8 to 2.3 L/ha in 200-1000 L of water. (0.7-0.9 L/ac in 80-400 L of water). (14 days).

Other chemicals that are registered and can be used are: Systox 24EC, 72EC (21 days); Guthion 50 WP, 12EC, 24EC (7 days); Metasystox 24EC (7 days); Vydate L24SN (7 days); Di-Syston 72EC, 15G (seed potatoes only) (90 days).

For more detailed information refer to the product label.

LEAFHOPPERS

The six-spotted leafhopper, which is found throughout potato growing areas of Canada, is important because it spreads the pathogens causing aster yellows or purple-top wilt disease. The adults usually take up the mycoplasma when feeding on infected plants and inject it, along with salivary juices, into healthy potatoes.

Leafhopper eggs overwinter on fall-sown cereals and grasses and hatch in May into tiny black wingless nymphs. These become light yellow after the first molt and grow rapidly, to reach maturity in about three weeks. The wedge shaped adults are 3 to 4 mm long, and olive green to dark greenish brown in color. As the cereals and grasses mature, the adult insects disperse to other plant species, including potatoes.

Newly developed adults can also migrate in large numbers from the southern United States into the prairie provinces and into southwestern Ontario. They begin to lay eggs on winter or spring-seeded cereals, as well as on grasses and early vegetables.

Another species, the potato leafhopper, may also sometimes occur in southern Alberta. While feeding, this leafhopper injects a toxin into the plant, which results in hopperburn, a yellowing and curling of the tips and margins of the leaflets, which ultimately turn brown and brittle. The plants can die early and the yield may be reduced.

Cultural control of these insects consists of keeping the fields and nearby crops as well as headlands and adjoining areas clean of weeds to reduce breeding sites. Where leafhopper populations are large, and especially if purple-top wilt has been found in a grower's field or on neighboring farms, control measures must be taken.

The following insecticides are effective for leafhopper control in Alberta.

Ambush EC (permethrin) at 140-200 mL/ha in 325-450 L of water (55-80 mL/ac in 130-180 L of water). (1 day).

Belmark (fenvalerate) at 100-300 mL /ha in 225-325 L of water (40-120 mL/ac in 180-220 L of water). (7 days).

Cygon 480E, 4E (dimethoate) at 550-1100 mL/ha in 200 L of water (225-450 mL/ac in 80 L of water). (7 days).

Furadan 10G (carbofuran) at 32.5 kg/ha (13.2 kg/ac).

Furadan Flowable at 1100 mL/ha in 800-1000 L water (445 mL/ac in 325-400 L of water). (7 days).

Malathion 500E, 50EC at 1.5-2.0 L/ha in 1000 L of water (0.6-0.8 L/ac in 400 L of water). (3 days).

Methoxychlor EC (methoxychlor) at 3.3-10.5 L/ha in 400 L of water (1.3-4.3 L/ac in 40-160 L of water). (7 days).

Monitor (methamidophos) at 1.8 - 2.3 L/ha in 200-1000 L of water (0.7-0.9 L/ac in 80-400 L of water). (14 days).

Supracide EC (methidathion) at 1.1 L/ha in 110 L of water (0.4 L/ac in 45 L of water). (14 days).

Temik 10G (aldicarb) at 22.5 kg/ha (9 kg/ac). (90 days).

Thiodan EC (endosulfan) at 1.5 L/ha in 450-550 L of water (0.6 L/ac in 80-400 L of water). (14 days).

PLANT BUGS

The tarnished plant bug is the most destructive of the several species of plant bugs. It feeds by piercing the plant tissues and sucking the sap, in the process destroying flowers and curling leaves and growing tips. The insect also spreads the pathogen causing spindle tuber.

The yellowish-brown adult overwinters under any available shelter, especially under plant debris and under semi-erect plants left from the previous crop. The insects become active very early in the spring, at which time they attack a variety of flowering plants. The adults are strong fliers and are able to travel over large distances.

The eggs are laid singly into the plant tissues or into the flowers. Hatching occurs in about 10 days. The young nymphs are yellowish green at first; however, in the process of undergoing five molts they darken.

Cultural control consists of removing all weeds and plant material from the last crop, and under which the insects can overwinter. Plant bugs are not usually a problem in Alberta potato fields, however, if present are effectively controlled with those chemicals listed for Colorado potato beetle.

COLORADO POTATO BEETLE

The black and yellow-striped Colorado potato beetle is well known to every potato producer. This insect overwinters as an adult in the ground. In the spring, sometimes before the potato sprouts appear above ground, the beetles emerge to feed on any available plants belonging to the nightshade family, moving to potatoes when the shoots first appear.

The orange-yellow eggs are laid in bunches of a dozen or more on the undersides of the leaves. Depending on temperature, these hatch in 4-9 days. The hunch-backed reddish larvae have black heads and a series of prominent black spots on both sides. As voracious as the adults, the larvae rapidly pass through four stages (instars) and are fully grown within two to three weeks. At this point, the 10-13 mm long larvae work their way into the soil, where they form cells and change to yellowish, motionless pupae. They reemerge as adults about 5-10 days later.

There is only one generation per year.

In addition to their feeding, which if uncontrolled can completely strip potato plants within a short time, the Colorado potato beetle is thought to be capable of transmitting the pathogens causing spindle tuber and bacterial ring rot.

Potato beetles are able to thrive on a diet containing high concentrations of glycoalkaloids, because of a highly efficient detoxification system which may also play a part in detoxifying insecticides. The Colorado potato beetle is highly adaptable, and can develop resistance to a number of insecticides of different chemical families. The development of insecticide resistance can be reduced by alternating chemical applications between pesticides belonging to different chemical families, for example, chlorinated hydrocarbons and organophosphates. Refer to the list of chemical names earlier in this section for chemical types.
The following insecticides are recommended for the control of the Colorado potato beetle.

Ambush (permethrin) at 145-200 mL/ha in 325-400 L of water (55-80 mL/ac in 130-180 L of water). (1 day).

Belmark (fenvalerate) at 100-150 mL/ha in 450-550 L of water (40-60 mL/ac in 180-220 L of water). (7 days).

Decis 5EC (deltamethrin) at 100-150 mL/ha in 200-500 L of water (40-60 mL/ac in 80-200 L of water). (23 days).

Furadan 10G (carbofuran) at 32.5 kg/ha (13.2 kg/ac).

Furadan flowable at 550 mL/ha in 800-1000 L of water (225 mL/ac). (7 days).

Guthion SC (azinphos-methyl) at 1.3-1.8 L/ha in 150-200 L of water (0.5-0.7 L/ac in 60-80 L of water). (7 days).

Guthion WP at 850 g/ha in 150-200 L of water (225-345 g/ac in 60-80 L of water). (7 days).

Monitor (methamidophos) at 1.8-2.3 L/ha in 200-1000 L of water (0.7-0.9 L/ac in 80-400 L of water). (14 days).

Sevin XLR or SL (carbaryl) at 1.3 L/ha in 55-440 L of water. (500 ml/ac in 22-180 L of water). (7 days).

Supracide EC (methidathion) at 1.1 L/ha in 110 L of water (0.4 L/ac in 45 L of water). (14 days).

Temik 10G (aldicarb) at 22.5 kg/ha (9.0 kg/ac). (90 days).

Thinet 15G (phorate) at 23.9 kg/ha (9.7 kg/ac). Early control only.

TUBER FLEA BEETLE

The tuber flea beetle, *Epitrix tuberis*, has been a serious pest of potatoes in the state of Washington and in British Columbia since the 1920's. However, it was not found in Alberta until 1974, when it was discovered in several Edmonton home gardens. Since then it has been found as far south as Medicine Hat, and as far east as Mannville. To date it has not been confirmed in commercial fields.

The adult is a small beetle (2 mm) that has a dull black oval body covered with fine hairs and with reddish antennae and legs. Owing to the greatly enlarged femurs of the hind legs, the beetle is able to jump a considerable distance, thus the term "flea". Flea beetles may spread bacterial pathogens and the spindle tuber viroid. Damaged tubers may be unmarketable and are readily infected by scab and rhizoctonia.

The adults overwinter in or on the soil in protected places; they emerge in early to mid-June and begin feeding on various species of weeds, until the preferred garden plants emerge. Although the distance that the emerging adults can fly is not known, they are capable of travelling considerable distances later in the season.

The eggs are laid on the soil around the bases of the plants. After hatching, the larvae develop in the soil, taking between three and four weeks to complete development. The pupal stage lasts for another seven days. There is only one generation annually in northern and central Alberta, but there may be two generations in southern Alberta.

The adults chew "shot holes" into the leaves of potatoes, and a variety of crop plants, including tomato, pepper, eggplant, bean, cabbage, corn, cucumber, lettuce, radish, spinach, and various weeds. Larvae feed on the surface of the tubers, or they may tunnel to a depth of 6 mm. This results in a corky brown surface area, which may be mistaken for common scab. Another species *Epitrix cucumeris*, while less destructive to the tubers, can cause more foliar damage.

Russet Burbank is known to be susceptible; however, little work has been done on varietal resistance to date.

Two other species of flea beetles, the potato flea beetle and the western flea beetle, are also found in Alberta.

They are controlled by the same chemicals that are applied for the tuber flea beetle.

Cultural Control. The current crop should be located as far as possible from a previously infested site, and away from urban areas. Volunteer potato plants and weeds should be destroyed, and piles of plant material should be removed.

Chemical Control. Control is aimed at the adults, before they can lay their eggs. The following insecticides may be applied.

Ambush 50EC (permethrin) at 140-200 mL/ha in 325-450 L of water (57-80 mL/ac in 140-180 L of water). (1 day).

Thiodan 4E, 40EC (endosulfan) at 1.5 L/ha in 450-550 L of water (600 mL/ac in 180-220 L of water). (1 day).

Belmark 30EC (fenvalerate) at 100-150 mL in 450-550 L of water/ha (40-60 mL in 180-220 L of water/ac). (7 days).

Supracide 25EC (methidathion) at 1.1 L/ha in 110 L of water (445 mL/ac in 45 L of water). (14 days).

Alternative products and formulations that may be used include: Sevin 5 DU, 50WP, 85WP (carbaryl) (7 days); Guthion 50WP, 12, 24EC (azinphos-methyl) (7 days); Furadan 48SN (carbofuran) (7 days); Decis 5EC (deltamethrin) (23 days).

WIREWORMS

Several species of wireworms infest potatoes in Alberta. The yellow-brown "worms" are the larvae of slender black beetles, which are approximately 15 mm long.

These are known as "click" beetles for their ability to right themselves when turned onto their backs, by flipping into the air with an audible click. The adults do not attack the crop, however the larvae feed on potato seed pieces, reducing yields and even killing the vines. They can cause much damage, (up to 50 larvae have been known to congregate in one tuber) by chewing deep pits and tunnels into tubers, thereby reducing their saleability. More importantly, the wounds serve as entry points for the pathogens causing blackleg and rhizoctonia disease.

Adults emerge in the spring from the soil where they wintered. Shortly after mating, the female beetles lay up to 300 eggs in the soil. While many females oviposit in one location only, others will fly some distance to lay their eggs into several locations. Depending on environmental conditions, the larvae require between 2-5 years to reach their full size of approximately 2 cm.

A population density of one or more wireworms per square metre can cause serious economic losses to a potato crop. While most fields will not reach this level in Alberta, new fields that have been in sod during the previous year may harbor wireworms, and it is therefore advisable to test for them in such fields.

Several methods of surveying for wireworms are available, of which the simplest is baiting. Although this method provides a very poor estimate of wireworm density in a field, it is a quick way of determining whether the pest is present. Carrots and coarse ground whole-wheat flour buried about 10 cm deep into the soil are highly attractive and may be used as bait. Two or three tablespoons of the bait material are placed in a scrap of nylon mesh and buried, leaving the tail of the nylon protruding as a marker. The baits should be buried randomly over the field. The more bait locations used, the more readily any wireworms present are found. However, it should be remembered that baits do not work in soil that is either excessively wet or too dry.

Soil samples may also be used to determine the presence of wireworms. Dig and remove soil plugs about 20-30 cm in diameter and 30 cm deep when the soil temperature is between 10°C and 25°C. The soil samples should then be shaken through a sieve constructed of 6 mm screening,

and again through one made from 6 or 8 mesh window screen. Since wireworms rarely occur uniformly throughout a field, several samples should be taken at random. At least one sample per hectare is required to detect wireworms that are unevenly distributed.

Growers who detect wireworms should contact the entomologist at the Alberta Horticultural Research Center (see back cover) regarding expected damage if wireworms are present. Alternate fields should be considered if populations are high. The following chemicals are registered for the control of wireworm in potatoes.

Dyfonate 10G (fonofos) at 23 kg/ha in the furrow (9 kg/ac) or broadcast at 56 kg/ha (23 kg/ac). Broadcast immediately before seeding and harrow, disc or rototill into 12 cm of soil. Furadan 5G, Dasanit 15G, and Thimet 15G may also be used.

COLUMBIA ROOT KNOT NEMATODE

Although not known to be present in either Alberta or British Columbia at this time, the Columbia root knot nematode, *Meloidogyne chitwoodi*, has caused severe losses to potato growers in the states of Washington, Oregon, Idaho, and in northern California, and millions of dollars are spent each year to control this and related species. The Columbia root knot nematode is able to move only a few metres annually on its own, but it is spread readily through the transport of infested potatoes, in soil clinging to farm implements and in irrigation water.

Root knot nematodes seriously affect root growth, yield and quality of potatoes. The above ground symptoms are not readily apparent, but they may consist of various degrees of stunting, lack of vigor, and wilting under moisture stress. Infested roots have knot-like cysts that are readily identified. Potato tubers may be heavily infected without showing external symptoms. In some cultivars, such as Russet Burbank, small raised galls or swellings appear on the tubers above the nematodes, and the internal tissue below the galls is necrotic and brownish. Galls may be solitary or bunched. Adult females are visible just below the surface as glistening white, pear-shaped bodies surrounded by a brownish layer of host tissue.

The potential impact of the Columbia root knot nematode on Canadian agriculture is so serious that areas in which the pest occurs are under federal quarantine, and no plant material from such quarantined areas may be imported into Canada. If the presence of the Columbia root knot nematode is suspected (in potatoes or other crops, such as cereals), samples of the suspect plant material should be sent immediately to the nearest diagnostic laboratory (see back cover).

Home gardeners often illegally import potatoes from the USA and other countries. They may unknowingly jeopardize Alberta's potato industry by importing nematodes and other unwanted pests.

WEED CONTROL

INTRODUCTION

Studies of the competition between potatoes and annual weeds indicate that a weed-free period between planting and the time of the canopy closure is necessary for the prevention of yield losses. If germinating weeds grow rapidly when the crop canopy deteriorates later in the season, they can create serious problems during harvesting.

To control weeds growers should use all available methods. Preventative methods should be geared at controlling weeds in headlands and shelterbelts and preventing the entry of new weeds via equipment, livestock, and feed manure. In addition, growers should integrate their cultural operations with herbicidal weed control methods. In general, weeds that have emerged by the time the crop is coming through can be controlled by hilling operations. Preemergence herbicides should then be applied just after hilling, assuming the cultivation is done when only a few potato plants have emerged (ground crack). Additional cultivation after the herbicide treatment should ordinarily not be required. Postemergence herbicides will provide the best results when broadleaved weeds are small (3 cm or less) and actively growing.

The major weeds that Alberta potato growers are likely to encounter are redroot pigweed, lamb's-quarters, wild oats and green foxtail. In addition, kochia can be a problem weed in southern Alberta, and volunteer wheat and barley are occasional problems following a dry fall in a cereal crop rotation. Smartweeds frequently infest low-lying areas of a field.

The above weeds can be controlled by selecting the proper herbicidal program. However, wild tomato (*Solanum triflorum* Nutt.) and wild sunflower are two annual weeds for which no satisfactory herbicidal control is available. These weeds can be readily controlled in cereal crop rotations by chemicals and by crop competition. Two native perennials, which may occur in patches after new land breaking in southern Alberta, are skeletonweed (*Lygodesmia juncea*) and sand dock (*Rumex venosus* Pursh). Herbicidal control recommendations are not available for skeletonweed or for sand dock.

Perennial weeds, particularly broadleaved species, should be eliminated prior to planting. At present, no chemicals are registered for control of Canada thistle and perennial sow thistle in potatoes. Quack grass, a serious weed if permitted to grow unchecked, can now be controlled or suppressed by several herbicides.

To select the weed control program for a particular field, growers should identify the major weed species and match these up to one or more of the appropriate herbicidal treatments. Growers should have a good knowledge of their weed problems from previous years as this information is essential for selecting pre-plant incorporated herbicides.

Not only is the correct choice of a herbicide important, several other factors can also affect the success or failure of a herbicidal application. These include timing, accuracy of application and rate. Postemergence herbicides must be applied at the most susceptible stage of the weed. Early treatment is recommended in cases where leaf stages of the weed are not indicated. Equipment (nozzles, gauges, pumps) should be in good condition and the application rate of the sprayer should be carefully calibrated to the desired output. Organic matter and soil texture affect the rates of preplant and preemergence herbicides. Where a range of rates is given, the low rate is for low organic matter soils and sandy soils. Similarly, if a range is given for postemergence herbicides, the lower rate should be used for light infestations and good growing conditions.

HERBICIDAL RESIDUE

Alberta potato growers should refrain from using Tordon 202-C (picloram + 2,4-D) and Glean (chlorsulfuron) on land rotated to potatoes. Following are some guidelines for cases in which these herbicides have been applied at the recommended rates.

In the Brown and Dark Brown soil zones of Alberta, land treated with Glean should not be used for potato production for a minimum of four years following the year of Glean application. In the Black soil zone with pH less than 7.5, this waiting period can be reduced to 2 to 3 years as the rate of breakdown for Glean is increased by lower soil pH.

Following the use of Tordon 202-C, potatoes should not be grown until the fifth year. Manure from animals which have been fed Tordon 202-C treated straw, will contain residues of picloram at levels sufficient to injure potatoes. Potatoes which have absorbed picloram will show severely cupped leaves (fiddleheading) and abnormal leaf veins. (See photograph.)

Banvel residues produce similar symptoms to those caused by picloram. Banvel applications in the spring of the preceding year at rates recommended for cereals should not cause any injury; however, post-harvest treatments or higher rates of Banvel will likely injure potato crops in the following year. Sprayers that have been used to apply either Banvel or Tordon 202-C should be thoroughly cleaned prior to use on potatoes. Where Lontrel (clopyralid) has been used, growers should not plant potatoes until after the second year following treatment. As more information on Lontrel persistence is developed this waiting period may not be required.

Where Treflan or Rival (trifluralin) have been used at recommended rates in the previous year, growers can plant potatoes without risk.

Atrazine usage in corn can result in potentially harmful residues. The persistence of atrazine is closely related to the rate of its application. Since these rates for use in corn vary widely, no generalized safe cropping interval can be formulated. Growers should conduct a bioassay test by growing potatoes in the treated soil and compare these to potatoes grown in similar soil but free of any herbicides. This can be done in the year before a planned potato planting, or potatoes can be planted in pots of soil in the spring.

Similar precautions to those suggested for atrazine also apply to Princep (simazine) and Sinbar (terbacil). Simazine can be used in corn and alfalfa, while Sinbar is used only in alfalfa. Problems with atrazine, simazine and terbacil have not been reported to the regional crops laboratory in Brooks, Alberta, but these herbicides could create problems with potatoes.

Growers planning to lease land should obtain a record of the herbicides used during the past five years for the fields concerned. They would be well advised to include a statement in their lease agreement indicating that neither Tordon 202-C nor Glean was applied in the previous four years.

Table 11, following the herbicide descriptions, is a summary of chemicals registered for weed control in potatoes.

CHEMICALS REGISTERED FOR WEED CONTROL IN POTATOES

EPTAM (EPTC) - Chipman Chemicals

Formulations. Eptam 8E, emulsifiable concentrate 800 g/L, available in 22.7 L containers. Granular 10 G is available in 22.7 kg bags.

Registered Mixes. Eptam 8E - liquid fertilizer. Eptam 8E + granular fertilizer (except for nitrate based fertilizer). Eptam 8E + Lexone or Sencor.

Weeds Controlled

Annual Grasses
Annual blue grass
Annual rye grass
Barnyard grass
Foxtails (green, yellow)
Volunteer grains
Wild oats

Perennial Weeds
Quack grass (see label)

Annual Broadleaf Weeds
Common chickweed
Corn spurry
Henbit
Lamb's-quarters
Hairy nightshade
Prostrate pigweed
Purslane
Redroot pigweed
Tumble pigweed

Timing. Apply just prior to planting, or at drag-off, or postemergence or with sprinkler irrigation (herbigation).

Fall application is not recommended for southern Alberta (chinook belt).

Rates. Before, planting, or at drag-off 4.3 - 8.5 L/ha (1.7-3.4 L/ac). Postemergence rate by sprinkler irrigation or tank-mixed with Lexone or Sencor is 4.3 - 5.5 L/ha (1.7 to 2.2 L/ac). Water volume for Eptam is 100 L/ha (40 L/ac) or more. For the tank mixture with Lexone or Sencor, use 200 - 300 L/ha (80 - 120 L/ac).

Incorporation. Following application of Eptam 8E or 10 G, the product should be incorporated immediately (within minutes) into the soil. The incorporation can be made with several types of implements. If using power-driven cultivation equipment, set the implement to cut 5 to 8 cm deep. Tandem discs should be set to cut 10 to 15 cm and operated at 7 to 9 km/h followed by harrows. Incorporation should be done twice in different directions. Field cultivators are recommended for incorporation only for lighter soils in good tilth. Use 3 to 4 rows of sweeps spaced at 18 cm intervals or less and staggered so that no soil is left unturned. Cut 10 to 15 cm deep at 10 km/h or faster. The second incorporation must be made at an angle to the first. Spike-tooth harrows should be pulled behind the cultivator. Use sweeps that are 18 cm or wider.

Application. Standard and low pressure nozzles delivering the desired water rate can be used. Low pressure nozzles help to eliminate spray drift. When applying Eptam 8E with granular fertilizer, a minimum of 200 kg/ha (80 kg/ac) of fertilizer is required. See label for further instructions.

How It Works. Eptam is taken up by the roots and shoots of a germinating weed. The Eptam taken into the weed disrupts and stops further growth. Eptam is not persistent in the soil, however it will give effective weed control for approximately 6-8 weeks.

Expected Results. Eptam controls a wide variety of weeds during the early stages of crop development. Eptam controls the weeds before they can compete for moisture and nutrients needed by the crop. Since Eptam is absorbed by the weed shoot, most affected weeds will not emerge. Numerous chlorotic and bleached shoots may be visible by removing the top few centimetres of treated soil.

Significant reductions in weed control can occur on soils which have been treated with Eradicane, Eptam or Sutan for two years or more. Poor results can also be expected if conditions are not suitable for soil incorporation such as on wet or cloddy soils. Eptam is very soluble in water; excessive moisture may cause leaching.

Storage: Heated storage not required. Store away from seed and fertilizer.

LEXONE, SENCOR (METRIBUZIN) - DuPont, Chemagro

Formulations. Lexone L 480 g/L, available in 10 L containers. Lexone D.F., 75% dry flowable, is available in 2.5 kg containers. Sencor 500 Flowable, 500 g/L, is available in 4 L containers. Sencor 750 water dispersible granules (750 g/kg) is available in 1.5 kg bags.

Registered Mixes. Lexone or Sencor + EPTAM, Sencor + Dual*, Sencor + Dalapon, Sencor + Fusilade, Lexone + Fusilade, Sencor + Gramoxone.

To tank mix two herbicides, fill tank ¼ full and with the agitator running add the appropriate amount of metribuzin. Continue to agitate and fill the tank to ¾ full then add the appropriate amount of the second herbicide. Fill tank and continue to agitate until it is sprayed out.

Weeds Controlled. Lexone 75DF or Sencor 75DF at 0.375 kg/ha (0.15 kg/ac) is equivalent to metribuzin at 0.28 kg ai/ha and will control the following weeds:

Ball mustard
Chickweed
Corn spurry
Lamb's-quarters
Stinkweed
Volunteer canola-rape (not TTC)
Wild mustard
Tartary buckwheat
Hemp nettle
Annual smartweeds
Common groundsel
Wormseed mustard
Shepherd's purse

Additional weeds to those listed above controlled by Sencor 75DF or Lexone 75DF at 0.75-1.5 kg/ha (0.3 to 0.6 kg/ac), or equivalent to metribuzin 0.56 - 1.12 kg ai/ha are:

Barnyard grass
Foxtails (green and yellow)
Cocklebur
Russian thistle
Common ragweed
Dandelion (seedling)
Henbit
Prostrate pigweed
Wild buckwheat

Weeds Controlled by Tank Mixtures. Eptam + Lexone or Sencor controls the weeds listed under the Eptam label plus those for metribuzin at 0.28 kg ai/ha. Sencor or Lexone + Dual controls those weeds listed for metribuzin at 0.28 kg ai/ha plus green foxtail and barnyard grass. Sencor + Dalapon controls those weeds listed for metribuzin at 0.56 - 1.12 kg ai/ha and suppresses emerged quackgrass. Sencor + Fusilade controls those weeds listed for metribuzin at 0.28 kg ai/ha plus grassy weeds and suppresses quack grass.

Rates and Timing. Check label for formulations other than those listed below.

On nonirrigated potatoes apply metribuzib early post-

*At the time of writing (January, 1986), Dual was submitted for registration. Please check registration status before purchasing.

emergence before weeds are 4 cm tall at the following rates:

Lexone 75DF 350 g/ha (140 g/ac)
Sencor 75DF 375 g/ha (150 g/ac)

On irrigated potatoes in southern Alberta, apply preemergence, early postemergence or split application (preemergence and postemergence) at the following rates:

Lexone 75DF from 0.64 to 1.4 kg/ha (265-565 g/ac) depending on type of application.
Sencor 75 from 0.75 to 1.5 kg/ha (300 - 600 g/ac).

Use the low rate for small weeds or when the product is applied preemergence. The maximum rate should only be used as a "rescue" treatment to control tall weeds.

Cultivar Tolerance. Potato varieties vary in their tolerance to rates listed for irrigated potatoes as shown in the following table.

Table 10. Tolerance of various potato cultivars to preplant incorporated (PPI) and postemergence applications of metribuzin.

	Metribuzin (kg ai/ac)			
	Soil	PPI	Postemergence	
Potato Cultivars	0.2	0.4	0.2	1.4
Atlantic	T	S	T	S
Batoche	T	S	T	S
Carlton	T	T	T	T
Conestoga	T	T	T	T
Kennebec	t	-	t	-
Lemhi Russet	-	-	T	S
Nooksak	T	T	T S	S
Norchip	t	t	t	t
Norgold Russet	T	T	T	T S
Norland	-	-	T	T
Red Pontiac	T	T	T	T
Redsen	-	-	S	S
Rhine Red	T	S	T	S
Rideau	T	S	S	S
Russet Burbank	T	T	T	T
Snagre	t	-	t	-
Shepody	T	S	S	S
Superior	-	-	-	-
Viking	-	-	-	-
Warba	-	S	S	-
Yukon Gold	T	T	T	T

T - tolerant, at least 2 years of testing
t - tolerant, only one year of testing
S - susceptible, tested 2 or more years
- - no data

Application Notes. Apply metribuzin with 100 L/ha (40 L/ac) of water at 200-275 kPa. If tank mixture with Eptam is used, then incorporate following directions for Eptam.

Restrictions: Do not apply metribuzin to coarse-textured soils with less than 2% organic matter. Weed control may not be adequate on soils with 10% organic matter or higher. Rotation crops such as onions, celery, peppers, cole crops, lettuce, spinach, beets, rutabagas and vine crops are sensitive to metribuzin and may be injured if planted in metribuzin-treated soil during the year of application and the year after.

How it Works: Metribuzin is a systemic herbicide absorbed by leaves and roots and translocated to new growth. It inhibits photosynthesis with subsequent browning and death of the weed.

Expected Results. Metribuzin will control the designated weeds under ideal conditions; however, significant reduction in control can occur if the weeds are in poor growing condition (drought), if they are too large, or if there is poor coverage of the chemical.

Storage. Metribuzin is not damaged by freezing. Store in a cool dry place and avoid large temperature fluctuations. It is preferable to store Lexone L and Sencor 500 in warm storage.

AFOLAN, LOROX (Linuron) - Hoechst, DuPont

Formulation. Afolan F, suspension formulation containing 450 g/L linuron is available in 8 L containers. Lorox L, suspension formulation containing 480 g/L, is available in 10 L containers.

Weeds Controlled.

Chickweed
Corn spurry
Cow cockle
Hemp nettle
Kochia
Wild buckwheat
Lamb's-quarters
Prostrate pigweed
Purslane
Ragweed
Redroot pigweed
Smartweeds (annual)
Sherpherd's-purse
Stinkweed
Stork's-bill
Tartary buckwheat
Wild mustard

Weeds Suppressed. Green and yellow foxtail when treated in the 1-3 leaf stage.

Rates and Timing. Apply preemergence to potatoes and when weeds are small at the following rates:
Lorox 480L at 2.2-4.5 L/ha (0.9-1.8 L/ac)
Afolan 450F at 2.8-5.0 L/ha (1.1-2.0 L/ac)

Application rates. Apply linuron with 300 L/ha (120 L/ac) of water at 275 kPa. Use 50 mesh screens and line strainers. Ensure adequate agitation.

How It Works. Linuron is a systemic herbicide which is absorbed through both the foliage and root system of the plant. Once in the plant it strongly inhibits photosynthesis. Affected plants appear chlorotic (yellow), stunted and they finally die 10-14 days after treatment. Irrigation or precipitation is required to activate linuron.

Expected Results. The initial effect of linuron on weeds is leaf-tip burn beginning on the older leaves. This is

followed by a water soaked wilted appearance, progressive yellowing, stem collapse and eventual browning and plant death.

Storage. Cannot be stored below freezing temperatures as settling may occur. Shake well before using.

GRAMOXONE (Paraquat) - Chipman Chemicals

Formulations. Water soluble solution, 200 g/L, is available in 4 L containers.

Registered Mixes. Sencor + Gramoxone

Weeds Controlled. Most annual weeds are killed with one application. Gramoxone provides only top growth control of perennial weeds.

Timing. Apply up to ground crack only for Russet Burbank; for other varieties apply up to the time the stems are 5 cm high (approximately one week after ground crack).

Rate. Apply 2.7-4.2 L in 300-500 L/ha of water (1-1.75 L in 120-200 L/ac) for top growth control of perennials and of annual grasses and annual broad-leaf weeds.

Note. Application to exposed or emerged potato foliage will cause temporary injury and chlorosis. Do not apply to emerged potato foliage in the evening, or to emerged potatoes under moisture stress caused by extremely dry soil conditions, or to emerged early potatoes. The use of diseased seed and cut seed that is not vigorous will make potatoes more susceptible to injury by postemergence Gramoxone sprays. This treatment can eliminate cultivation, but has no residual action and will not control weeds that germinate after treatment.

Application Notes. Weeds should be thoroughly covered by spraying. For dense weed growth use the higher water volume. Apply with ground equipment only, using 300-500 L/ha (120-200 L/ac) of water and a pressure of 300 kPa.

How It Works. Gramoxone is absorbed by leaves and stems but is not translocated. The paraquat destroys green plant tissue by interfering with photosynthesis and causes massive cell disruption.

Expected Results. Gramoxone provides fast and virtually complete annual weed kill with one application; however, volunteer cereals, knotweed and wild buckwheat may regrow after receiving one treatment.

Gramoxone is inactivated on contact with soil, therefore it has no residual effect. Poor results may occur if muddy water is used or if foliage is inadequately covered. Rain will not reduce the effectiveness of Gramoxone once the spray solution has dried on the plant tissue.

Storage. Requires heated storage.

ROUNDUP (Glyphosate) - Monsanto

Formulations. Aqueous solution, 360 g/L. Available in 1, 4 and 10 L containers.

Weeds Controlled. Controls a wide range of annual and perennial weeds. Check label for details on weeds of concern.

Timing and Rate. Roundup is registered for application prior to planting when spring weed growth is advanced. Use a reduced rate, 2.5 L/ha (1 L/ac), for seasonal quack grass control in spring or in fall after harvest, applied when quack grass is in the 3 to 4 leaf stage (8-10 cm of new growth) and actively growing. Prior to application rhizomes should be undisturbed by cultivation. Roundup may be applied up to and after quack grass has been exposed to temperatures down to -5°C. Apply in 50-100 L/ac (20 to 40 L of water/ac). Allow five or more days after application before cultivating.

Roundup at 2.5 L/ha (1 L/ac) is also registered for Canada thistle control (in the rosette stage) in conjunction with summerfallow. Consult label for rates to control other weeds and for other registered uses.

Application Notes. Do not use sprayers constructed of galvanized steel or unlined steel. Tanks, lines and fittings made of stainless steel or plastic are permissible. Clean water free of suspended clay, silt or organic matter must be used.

How It Works. Roundup is a systemic herbicide which moves through the plant from the foliage into the root system. It inhibits the biosynthesis of aromatic amino acids.

Expected Results. Visible effects on most annual weeds occur within 2-4 days, but effects on perennial weeds may not be apparent for 7 to 10 days. Visible effects are a gradual wilting and yellowing of the plant which advances to complete browning of above ground growth and deterioration of underground plant parts. Extremely cool or cloudy weather at treatment time may delay activity and visible effects of this product. Roundup is nonselective and acts on all living plants in a similar fashion. Since Roundup has no soil activity it does not control seeds or unemerged weeds and it is therefore important to watch for reinfestation.

Conditions Resulting in Incomplete Weed Kill. Several conditions may cause reduced effectiveness of Roundup. These include:

- rainfall within 6 hours after application
- inadequate spray coverage of target species
- premature application to perennial species
- using a water supply which contains suspended silt, clay or organic matter
- extreme plant stress due to drought and high temperatures at treatment time

- disturbance of perennial weed root systems by cultivation prior to treatment.

Storage: Heated storage not required.

HOE GRASS 284
(Diclofop-methyl) - Hoechst

Formulation. Emulsifiable concentrate 284 g/L. Available in 20 L containers.

Registered Mixes. No registered mixes for use in potatoes.

Weeds Controlled and When Applied
Wild oats (1-5 leaf stage)
Green and yellow foxtail (1-4 leaf stage)
Barnyard grass (1-4 leaf stage)
Persian darnel (1-3 leaf stage)
Volunteer corn (15-25 cm tall)

Rates. Apply Hoe Grass 284 at 3.5 L/ha (1.4 L/ac) in 100 L/ha (40 L/ac) of water at 275 kPa using ground equipment. Hoe Grass may be applied by air with a minimum of 35 L of water (14 L/ac).

Application Notes. Nozzles should be tilted 45° forward to ensure better coverage. Use flat fan nozzles only in a field sprayer. During periods of stress (hot and/or dry conditions, or very low humidity), when plants are not actively growing, reduced weed control may result. Do not mix Hoe Grass 284 with any other herbicides, insecticides, fungicides, fertilizers or any other chemicals or additives. Hoe Grass must be applied before the use of any broadleaf herbicide. A time interval of 4 days after application of Hoe Grass is required to prevent a reduction of grassy weed control.

How It Works. Hoe Grass acts both by contact and systemic action. Uptake is primarly through the leaves. The chemical is then translocated to the growing point where it interferes with growth.

FUSILADE (Fluazifop-Butyl) - Chipman Chemicals

Formulation. Emulsifiable concentrate 250 g/L. Available in 8 L containers.

Registered Mixes.
Fusilade + Lexone, and Fusilade + Sencor
(Do not use Agral 90 with Fusilade in a tank mix).

Weeds Controlled. Grass weeds (see below in Rate section).

Timimg. Corn, Persian darnel, wheat, barley, wild oats, wild proso millet in the 2-6 leaf stage; 2-4 leaf stage of yellow and green foxtail; 3-5 leaf stage of quack grass.

Rate. Apply Fusilade in 100-300 L/ha (40-120 L/ac) of water at 200-300 kPa. Use the following range of rates according to weeds present:
- corn 600 mL/ha (240 mL/ac)
- barnyard grass, Persian darnel, barley, wheat 800 mL/ha (320 mL/ac)
- wild oats, wild proso millet 1 L/ha (400 mL/ac)
- green and yellow foxtail suppression 1.0 to 1.4 L/ha (400 to 570 mL/ac)
- quack grass (tilled land) 2L/ha (810 mL/ac)

Application Notes. Apply with ground equipment using flat fan nozzles. Fusilade is less effective when plants are stressed by lack of moisture, low temperature and/or very low relative humidity. Apply 3 days before the use of any broadleaf herbicide. Rhizomes of quack grass should be thoroughly fragmented by tillage prior to application. Do not cultivate for five days after applying. Add Agral 90 at the rate of 1 L for every 1,000 L of spray solution (0.1% by volume). Do not add Agral 90 when tank mixed with other herbicides.

How It Works. Fusilade is readily translocated and inhibits cell division in the shoot apical meristem.

Storage. Not affected by freezing.

POAST (Sethoxydim) - BASF

Formulation. Emulsifiable concentrate 184 g/L. Available in 7 L containers.

Registered Mixes. None registered for potatoes.

Weeds Controlled
Green and yellow foxtail
Barnyard grass
Wild oats
Barley
Oats
Wheat
Corn
Persian darnel
Wild proso millet
Quack grass

Timing. Apply Poast when weeds are 1-6 leaf stage or 10-15 cm in height. Do not apply with 80 days of harvest.

Rate. Apply Poast at the following rates in 50-110 L of water/ha (20-45 L/ac) at 275-425 kPa. Assist Oil Concentrate must be added at a rate of 0.5 L/ha (200 mL/ac) for ground application and 0.5 - 1.0 L/ha (200-400 mL/ac) for aerial application.

Poast Application Rates.

0.8 L/ha (325 mL/ac)	1.4 L/ha (570 mL/ac)	1.6 L/ha (650 mL/ac)	1.9 L/ha (790 mL/ac)	4.4 L/ha (1.8 L/ac)
Green foxtail Yellow foxtail Barnyard grass Wild proso millet Persian darnel	Wild oats	Wild oats (heavy) Wheat Oats	Barley	Quackgrass

For quack grass suppression, apply 4.4 L/ha or 2.7 L/ha + 2.0 kg/ha ammonium sulphate when quack grass is in the 1-3 leaf stage. Quack grass rhizomes must be well fragmented with cultivation prior to application.

Application Notes. Tilt nozzles forward 45° for better coverage.
Stainless steel 80° flat fan nozzles are optimum. Flood jet or hollow cone nozzles are not recommended. Treat when weedy grasses are actively growing, soil moisture is good and the crop is small enough to permit thorough spray coverage. DO NOT ALLOW SPRAY MIXTURE TO SIT OVERNIGHT, AS THE ACTIVE INGREDIENT IS HYDROLYZED AND SUBSEQUENTLY INACTIVATED. With the agitator running, fill the spray tank with one-half the required amount of water. Add Poast, followed by the Assist Oil Concentrate, and then the remainder of water. Thoroughly clean the sprayer after use by flushing with warm water and detergent. Allow 4 days between the application of Poast and any other chemical. Control of grasses growing under drought, flooding or prolonged cool temperatures under 15°C. may be reduced or delayed. Escapes or re-tillering may occur under prolonged stress conditions. Do not apply on grasses stressed longer than 20 days owing to lack of moisture as unsatisfactory control will result.

How It Works. Poast is absorbed by the leaves and moved systemically within the plant. It inhibits cell division in the shoot apical meristem.

Storage. Store product in a cool, dry place.

Table 11. Summary of Potato Herbicides and Weeds Controlled.

Herbicide and Application Timing / Weed Control Rating	Redroot pigweed	Smartweeds	Mustards	Lamb's quarters	Russian thistle	Wild buckwheat	Kochia	Wildoats	Barnyard grass	Green Foxtail	Volunteer cereals	Canada thistle	Quack grass	Residual Activity
BEFORE PLANTING														
Eptam + Sencor/Lexone PPI	G	G	G	G	F	G	F	E	E	E	G	P	P	1 season
Eptam PPI	G	P	P	G	P	P	P	E	E	E	G-E	P	G[a]	5-6 weeks
Roundup														
Roundup												E	E	none
Dual † Sencor/Lexone PPI	G	G	G	G	F	G	F	P	E	E	P	P	P	1 season
BEFORE CROP EMERGENCE														
Afolan, Lorox	E	G	E	E	F	G	G	P	P	P	P	P	P	1 season
Sencor, Lexone[c]	E	E	E	E	G	-	G	F	G	G	F	P	P-F	1 season†
BEFORE EMERGENCE - Ground Crack														
Gramoxone	E	F	E	E	G	P	G	F-G	G	G	F-G	P	G[e]	none
Gramoxone + Sencor[c]	E	E	E	E	E	E	E	G	G	G	F-G	P	P	1 season
AFTER EMERGENCE (small weeds)														
Sencor/Lexone[b]	E	E	E	E	-	P	-	P	P	F	P	P	P	1 season
Sencor/Lexone[c]	E	E	E	E	G	G	G	F	G	G	F	P	P-F	1 season°
Fusilade	P	P	P	P	P	P	P	E	E	F-G	E	P	G[d]	-
Fusilade + Sencor/Lexone	E	E	E	E	-	P	-	E	E	G	E	P	G[d]	-
Poast	P	P	P	P	P	P	P	E	E	E	E	P	G[d]	-
Poast + ammonium sulphate	P	P	P	P	P	P	P	E	E	E	P	P	P	-
Hoe Grass	P	P	P	P	P	P	P	E	E	E	G-E	P	P	5-6 weeks
HERBIGATION (weed free)														
Eptam	G	P	P	G	P	P	P	E	E	E	G-E	P	P	5-6 weeks

Ratings: E = excellent; G = good; F = fair (not commercially acceptable); P = no control to poor; - = information not available.

[a] For quack grass control, higher rate of Eptam required plus special incorporation.

[b] Sencor/Lexone at the low rate for all areas.

[c] Sencor/Lexone at higher rates for irrigated fields in southern Alberta, cultivar restrictions apply.

[d] For quack grass suppression, Fusilade and Poast must be applied at higher rates than annual weeds. Rhizomes must be well fragmented.

[e] Top growth control only.

POTATO STORAGE AND HANDLING

POTATO STORAGE MANAGEMENT

The potato tuber is the storage organ of the potato plant. In nature the tuber enables the potato plant to survive the winter by providing food reserves, in the form of starch, and allows the young potato plant to start growing the following spring. It is the food reserves, or starch, that growers, consumers and processors are interested in, but all too often it is forgotten that potato tubers are living organisms that consume oxygen, and food reserves, as well as give off carbon dioxide and heat. Growers attempt to manipulate physical factors, such as temperature, humidity, and storage atmosphere, that influence the life processess in the tuber, to suit their own requirements.

Physical factors such as temperature, humidity, and storage atmosphere can have tremendous influences over the life processes of the tuber. High temperatures cause the tuber respiration rate to increase and oxygen and food reserves are used up quickly. The end result is that the tubers lose weight. Freezing temperatures can cause ice crystals to form within the tuber damaging and killing cells. If the air surrounding the tuber has low humidity, water will move from the tuber to the air, resulting in weight loss. The oxygen concentration in the atmosphere surrounding the tuber is very important. If the oxygen content falls too low, cells within the tuber die and blackheart forms.

Sprouting is also a natural biological function of the tuber. However, in most circumstances it is not desired for consumption. It should be realized that sprouting occurs when the natural dormancy period of the potato tuber ends and environmental conditions are right, although sprouting can also be brought on by damage or injury to the tuber.

Disease is an abnormal condition that alters in some way the structure or life processes of an organism. In the potato tuber disease can be caused by microorganisms or adverse environmental conditions. Disease physically damages seed, or it may result in weak potato plants that don't yield well.

The potato tuber is a living organism that has certain requirements that must be met in order for it to maintain its life processes. Failure to recognize this and provide the necessary conditions can lead to disastrous consequences when tubers are put into storage.

The aim of storage management is to preserve the tuber in its best possible condition, with minimum loss in quality or material. No storage is able to improve the product placed in there, but much can be done to minimize losses.

This text concentrates on storage operation and management and does not discuss details of storage design and construction. However, there are several important properties of a good storage that growers need to be aware of. A potato storage should be well insulated to stabilize temperatures and to maintain the high humidity required. The structure must be adequate to withstand the high pressure of piled potatoes, and wind and snow loads. A good ventilation system capable of accurate temperature control, humidification and through-the-pile air distribution is required. The storage should be easy to clean, sanitize and maintain, and should provide for convenient access and handling of potatoes.

Growers who would like assistance with storage design are requested to contact the farm structures engineer at the Alberta Agriculture Lethbridge regional office.

VENTILATION

Ventilation is of extreme importance in maintaining temperatures, relative humidity and correct atmospheric conditions in the storage. Several ventilation systems can be used, but the most common is a fan and duct system which blends air to the correct temperature, adds humidity and blows the air through the potato pile. Ventilation rates for various classes of potatoes are:

	L/s/t (cfm/ton)
Seed	5-7 (10-14)
Table	7-8 (14-16)
Processing	8-10 (15-20)

Fans are selected based on 300 Pa static pressure and blending louvers are sized for 5 m/s air velocity. Duct size is designed to allow for moderate air velocity as high velocity results in high pressure loss, poorer air distribution, and lower fan efficiency. Table 12 provides a guide to maximum duct size. Air systems that permit regulating air flow to certain areas have most management flexibility. Indoor-outdoor differential controls permit optimum use of outdoor air for cooling. It is desirable to ventilate as little as necessary to maintain the required temperature, as weight loss caused by ventilation is proportional to the time ventilation is operated, not the volume of air moved. It is therefore better to run a higher volume of air intermittently, than a lower volume continuously.

STORAGE CYCLE

Several distinct storage phases exist. The best management of each depends on tuber conditions, weather and the end use or type of crop. These conditions and related management practices are summarized by Table 14 and discussed below.

Table 12. Maximum duct length (metres) for round ducts (spaced at 3.0 m (10 ft) in Potato Storage Bins.

Duct Size (mm)	Diameter (in)	Area m^2	Ventilation Rate 8 L/s/t (15 cfm/ton) Pile Depth - m (ft) 4.0 (13)	5.0 (16)	Ventilation Rate 10 L/s-t (19 cfm/ton) Pile Depth - m (ft) 4.0 (13)	5.0 (16)
250	10	0.05	4.6	3.7	3.7	3.0
300	12	0.07	6.6	5.3	5.3	4.2
375	15	0.11	10.4	8.3	8.3	6.6
410	16	0.13	12.4	10.0	10.0	8.0
450	18	0.16	15.0	12.0	12.0	9.5
510	20	0.20	19.0	15.3	15.3	12.0
610	24	0.30	27.4	22.0	22.0	17.5

Notes to duct design table:
1. Maximum duct velocity is 6.0 m/s (1200 ft/min).
2. Duct spacing is 3.0 m (10 ft); for closer duct spacing, maximum duct length can be increased in proportion to closer spacing.
3. Duct length should be shortened proportionally for greater pile depth or increase air flow.
4. This table can be used for other duct shapes of equivalent area.

Design Example:
What ducts are appropriate for a 15 m (45 ft) wide bin to be ventilated at 8 L s t (15 cfm ton); pile depth 5 m (16 ft).

Answer:
Look in column 2 under 5.0 m depth for a length close to 15 m. 15.3 m is opposite a 510 mm (20") duct. Perhaps a 450 (18") duct is more practical. Its maximum length is shown as 12.0 m, therefore it should be spaced at 12.0 15 x 3.0 m = 2.4 m (8 ft).

If the pile is shallower near the walls so it averages 4.0 m deep, 375 or 410 mm (15"- 16") ducts at 2.4 m spacing would be adequate.

Preharvest Period. Most storage problems usually occur in the field before harvest begins. Good storage helps deal with these problems, but may not overcome them. Some problems can be controlled but others, particularly weather-related ones, may not be controllable. Aim to place the best possible crop in storage. Tubers should be matured to resist damage, disease and weight loss. True physiological maturity is related to growing days, weather, variety and cultural practices. Vine killing to hasten maturity is desirable and should be done a minimum of 10 days prior to harvest.

The storage should be prepared well in advance of harvest. Check that all mechanical systems are working, ducts are clean and undamaged, and that fans and louvers work properly. Use an accurate thermometer to check ventilation controls.

Thoroughly disinfest the storage and all handling and harvesting equipment. Dampen earth floors, if any, in storages. If adverse conditions or special storage needs are known, plan appropriate allocation of storage space. Plan to harvest the most mature, or the most weather-susceptible crop (such as chipping potatoes) first. Consider light irrigation where feasible to improve soil conditions for harvesting.

Harvest Period. A bruise and damage-free harvest operation is essential. Mechanical injury is the number one problem world-wide in potato storage. Know and practise proper operation of harvester and handling systems. (Refer to the harvest management section). Weather, specifically temperature, has a great affect on the potato harvest. Producers should try to avoid harvesting tubers colder than 5°C; preferably they should be 10-15°C. Tubers that are around 3-5°C are very susceptible to shatter bruise. Tubers at 18-20°C and under slight moisture stress are highly susceptible to black spot bruise which is not visible. Adverse weather may result in severely injured, frosted, chilled or diseased potatoes. When feasible, these should be separated from normally healthy crops prior to storing.

Postharvest Curing Period. How potatoes are first treated in storage influences their performance thereafter. Immediately after harvest the tubers are most susceptible to weight loss and disease - the skin is damaged, respiration is greatest, and cooling may be required.

Potatoes normally should be cured at about 15° and 95% relative humidity for two weeks. This promotes wound healing and skin set. (Bacterial soft rot and frozen potatoes are the exception). Healing takes place most quickly at 20 - 25°, but so does the development of soft rot organisms; and therefore 15° is the best compromise for most situations. During this period, inspect the storage frequently, particularly if problem conditions exist.

There is not complete agreement on the preferred ventilation during this curing or suberization period. Near ideal conditions often exist in the pile with no ventilation air flow. This minimizes weight loss; however, at least some pile ventilation is desired twice a day to provide oxygen and reduce pile sweating. "Sweating", or condensation on surface tubers, results when the upper tubers are cooler than inside the pile. A small amount is

usually harmless, but it can encourage soft rot. With good humidity control and capacity, more or continuous ventilation is recommended. To reduce weight loss always run the humidifier when ventilating with outdoor air.

If cooling is required to bring the pile temperature down to 15°C, cool as quickly as possible, but never use air much colder than the desired storage temperature as tubers near the air ducts will be overchilled. A ventilation system with an outdoor temperature sensor is beneficial for cooling when outdoor temperatures are low enough.

When the pile requires warming to bring it to curing temperature, do so slowly, increasing temperature about 1°C per day. Warmer air applied to cool tubers will cause condensation on the tubers, which makes them more susceptible to bacterial soft rot infection.

Mid and Long-Term Storage. The objective is to maintain a consistent, ideal environment for the duration of the storage period. Long term storage demands more critical control than short term. Recommended conditions depend on crop conditions, variety, and intended use. General recommendations for storage temperatures are:

Seed potatoes	4-5°C
Table Stock	6-7°C
Processing - French fries	7-8°C
- Chips	9-10°C

Ventilation can be either intermittent or continuous. Intermittent ventilation, 2-6 hours twice a day, results in minimum weight loss and is generally recommended for table and seed potatoes. Continuous ventilation results in the most uniform conditions desired for chipping potatoes. Continuous ventilation may not be necessary in milder weather.

Marketing Period. Fresh and processing potatoes are particularly susceptible to injury during unpiling, trucking and processing if they are cold. Potatoes should be at least 7°C before they are moved. As chipping potatoes are held at 9 or 10°C they are not normally pre-warmed; however care in handling is still necessary. A storage facility containing several smaller (300-500 tonne) bins is far more flexible than a storage with only one or two 1000-1500 tonne units. Small units can be individually preconditioned prior to opening and moving.

Growers with chipping contracts may be required upon direction from their contracting processor to recondition Norchip prior to shipping and processing. When Norchips stored at 9-10°C are failing to produce light colored chips, reconditioning at temperatures ranging from 12-18°C or warmer may be required. The increased temperature causes an increase in respiration and a reduction in sugars which cause darkening of chips. Growers are advised to prewarm Norchip only following consultation with their processor as the higher temperatures can cause problems if the potatoes are not processed within one month after warming. The higher temperatures can cause more shrink, reduction in specific gravity, and sugar levels can increase at some later date. Although sprout inhibited, the potato's dormancy will be broken sooner and a condition called "irreversible senescense sweetening" may occur. This "old age" sweetening cannot be corrected.

Seed potatoes, when marketed late in the season, should also be prewarmed to break dormancy and reduce injury.

POST-STORAGE MANAGEMENT

This period is often neglected by producers. After potato bins are emptied, the storages, ventilation systems and other equipment should be rechecked. Check fans, louvers, and drive belts; make minor repairs; and order any parts or repairs required. Early maintenance allows time to order special parts and arrange for professional repair services if required. Jobs are often cheaper and more conveniently done if a service company does not have to make a special trip to the storage. Clean the storage of all potato residue and loose soil, and disinfect the storage to prevent build-up of disease organisms.

SPROUT INHIBITING

Seed potatoes obviously are not sprout inhibited. They should not even be put in a storage that has been used for sprout inhibitor treatment or has held potatoes treated with CIPC. Storing at 4° will generally suppress sprouting and control decay organisms in seed tubers. Seed stock should be warmed before marketing or before cutting and planting to break dormancy and promote sprouting. Processing and fresh market potatoes to be stored past January are normally treated with sprout inhibiting chemical (CIPC), and this is usually applied in November or December.

Sprout inhibiting raises the storage temperature, stresses the potato and causes conflict with normal storage management. It is desirable to circulate the sprout-inhibiting fog throughout the pile for a period of 36-48 hours, undiluted with outside air. Although the storage temperature will rise as much as 5°C, ventilation with outside air should be avoided.

The following procedure for storage operation after treating with CIPC is recommended. After initial application of the sprout inhibitor, ventilation fans are run for 1 hour every 12 hours to provide minimum air circulation, but with no outside air. After 36 hours commence ventilating with high humidity, to bring the pile temperature back to normal. Fans and controls should be covered with plastic for protection before using sprout inhibitors; however, to ensure freedom from CIPC they should be cleaned after treatment. Shut off electrical power and clean fans and controls of sprout inhibitor residue before continuing normal operation. CIPC is corrosive, and will clog refrigeration coils if it is not removed. CIPC is considered to be slightly toxic when inhaled or absorbed through the skin. Wear protective

clothing and avoid inhalation and skin contact when cleaning storage equipment after treating.

Application of Sprout Inhibitor. The chemical CIPC, sold as Sprout-Nip, is registered for use on storage potatoes in Canada and is the most common method of sprout inhibition used. This chemical is applied by specialized equipment and done by one contractor in Alberta. Contact Stan Chem Ltd., in Calgary for information on application. The advantages of in-storage sprout inhibition are: it eliminates one field operation (compared with applying MH60SG); and it allows some flexibility of treatment based on in-storage crop condition and marketing schedule. The disadvantages are: either all the potatoes or none in a storage bin are treated; the storages used for treatment cannot be used to house seed potatoes at a later date; and potatoes treated with CIPC cannot be stored in another storage near seed potatoes.

SPECIAL STORAGE PROBLEMS

Tables 13 and 14 summarize some of the special crop conditions and storage problems often encountered. A good storage ventilation system helps deal with many potato problems, and can save a lot of potatoes. A storage system cannot improve poor quality potatoes. (Garbage In:Garbage Out).

Very wet potatoes. These are susceptible to bacterial soft rot, and should be dried quickly. Operate the ventilation system continuously (with outside cooling air when it is available). Direct more air to the wet portion of the pile, if at all possible. Check potatoes about 50 cm below the surface as they are the last to dry. Temperature can be at 10-15°, unless soft rot is evident in which case the temperature should be lowered. Return to normal operation with high humidity as soon as free moisture is removed. A severely wet crop, with soft rot infection, should be stored separately, or not at all.

Frozen and/or severely chilled potatoes. Unfortunately, these conditions occur frequently in Alberta, often affecting the last part of a grower's crop to be harvested. Two problems are faced: preserving the crop in storage, and the quality of chill-injured potatoes for processing. Some crops do not recover from chilling injury at harvest.

Frozen tubers should be removed as completely as possible from a crop going into storage. It is however not possible to remove all frozen tubers as softening of tissue may not occur for several days after the tubers are harvested and already in storage. Fortunately a lot containing up to 5-10% frozen potatoes can be successfully stored with a good ventilation system. Frozen tubers will break down and rot unless continuous ventilation is used (without the humidification) to dry these rotted tubers. Drying can take up to two months, depending on severity of damage. Overventilation at lower humidity results in much higher shrinkage loss; however the excessive shrink loss may be necessary to save the crop. Frozen potatoes should be kept as cool as possible, taking into account the end use, to control bacterial soft rot. The normal and desirable higher-temperature curing cannot be accomplished.

Chilled potatoes, which have little danger of freeze-damage breakdown, can be treated more normally. They are ventilated continuously with high humidity air; however they must be warmed slowly to prevent condensation on the tubers which will encourage soft rot. A temperature increase of 1°C per day until they reach the desired curing temperature is suitable.

Because chilled potatoes may not respond to conditioning for processing, they should be checked for processing quality by the contracting processor. The Alberta Horticultural Research Center (Bag Service 200, Brooks, Alberta, T0J 0J0, phone 362-3391) will assess quality, including sugar levels, upon request. The experience of growers and processors in 1984 and 1985, when large lots of potatoes were chilled, indicates that Norchip may respond erratically to reconditioning and therefore testing of small sample lots is strongly recommended.

Disease and Rot. In attempting to store potatoes that have obvious tuber disorders, a grower should first ascertain the type of disease or diseases present, as control procedures may differ significantly. One control method may encourage proliferation of a second disease organism.

Soft rot is a common storage disorder and is treated in much the same way as frozen potatoes. The lot is ventilated continuously and kept as cool as possible (5-7°) to control soft rot. Normal curing must not be attempted since high temperatures accelerate soft rot bacteria. Growers should contact the Alberta Horticutural Research Center for assistance in identifying storage diseases.

STORAGE INSPECTION

Frequent checking of both the storage systems and the crop is essential. The storage should be designed to provide easy access to potato lots for inspection. Walk planks on the surface and soft-soled shoes help reduce damage to surface potatoes. Pile inspection should include checking at a few locations by digging below the pile surface where the warmest and dampest potatoes are usually found. Temperature probes, or electronic temperature sensors are helpful in checking for signs of heating, or increased respiration, indicating a potential problem. Pile temperature can be checked by lowering a thermometer into a vertical electrical conduit placed in the pile during filling. Odors can be one of the best indicators of storage conditions and impending disease or decay problems. Producers should use their sense of smell frequently in addition to mechanical and electrical monitoring devices.

Table 13. Management of some storage problems.

SPROUTING
- Keep below 5° (seed) or 7° (table stock)
- Apply chemical sprout inhibitor (not seed potatoes)
- Keep temperature steady

SHRINKAGE AND SOFTENING
- Minimize damage
- Control sprouting
- Store mature crops
- Cure adequately
- Store at coolest temperature acceptable for market
- Ventilate intermittently as required for temperature control
- Maintain high humidity, particularly when outside air is used for cooling

PRESSURE BRUISING
- Store mature crop, top-kill if required
- Cure adequately
- Keep pile depth reasonable
- Minimize shrinkage (high humidity)
- Damage is related to time in storage; short term can be stored deeper

BRUISING
- Minimize damage
- Mature crop
- More prominent above 7°
- Use a fungicide when filling storage

BACTERIAL SOFT ROT
- Do not store diseased potatoes
- Keep temperature low (5°C)
- Ventilate continuously
- Do not cure at higher temperatures
- Try to avoid wet harvesting

COLOR OF FRY OR CHIP
- Use recommended fertilizer, cultural practices
- Mature crop
- Cure adequately
- Keep temperature uniform
- Store at recommended temperature
- Precondition before marketing
- Watch for pre-harvest crop stresses
- Try to avoid pre-harvest chilling injury
- Consult with processor

CONDENSATION ON PILE OR ON CEILING
- Ventilate through the pile
- Ventilate continuously; some air can be passed to recirculate over the pile
- Add heat to back of storage so it warms the air returning over the pile about 2°
- Have adequate ceiling insulation
- Dark colored ceiling is better

HANDLING OF POTATOES

One object of this booklet has been to stress the importance of potato quality. Although many factors contribute to overall quality, mechanical damage is commonly the most important factor since it is largely controllable and because it causes losses in all potato lots. Reduction of harvest bruising was discussed earlier.

Following is a brief summary of practices that growers, packers and processors can apply to help reduce mechanical damage of potatoes. (Not all of these processes may apply where potatoes are flumed or where an automatic scoop is used).

1) Potatoes should be at least at 7°C before they are moved out of storage and to the packaging facility or processor.
2) If a front-end loader is used to carry potatoes from the pile to the conveyor hopper it must be designed and operated properly. A well designed loader bucket has a straight and bevelled leading edge; sloped back sides with rounded edges; hydraulic tilt control; skids or rollers on rear, underside of the bucket; and is of heavy-duty construction. The bucket is widened to increase capacity, not deepened. Prior to entering the pile the rear of the bucket is approximately 10 cm from the floor and the leading edge touching. The bucket enters the pile gently and the front is tilted upward slowly as the loader reverses out of the pile. The load is dumped slowly onto the receiving hopper keeping the front of the bucket as close to the top of the pile as possible.
3) Drops anywhere in the system should not exceed 15 cm.
4) All pilers, loaders, hoppers and packing line equipment should be equipped with padding or deflectors where potatoes will hit. Sharp points and pinching or scraping conditions must be eliminated.
5) As with the harvest operation all personnel should be trained to operate equipment properly, but more importantly they should be made aware of the importance of bruise prevention and encourage to look for deficiencies in the system.

TEMPERATURE 7°C MINIMUM
DROPS 15 CM MAXIMUM
PADDING, DEFLECTORS
TRAINED PERSONNEL
PROPER EQUIPMENT OPERATION

Table 14. Potato storage management summary.

STORAGE PERIOD	GENERAL REQUIREMENTS	CROP CONDITIONS				
		NORMAL	VERY WET	CHILLED	FROSTED	DISEASE/ROT
PRE-HARVEST	Check equipment. Clean & disinfect storage & handling equipment. Mature crop/top kill.	Apply pre-harvest irrigation as required for softening soil		Harvest chippers earlier than (A) or (C) to reduce risk of poor chip quality.	prepare to segregate this crop (if feasible) in storage.	prepare to segregate this crop in storage. may be able to segregate areas of field.
HARVEST	Go gentle. No drops more than 15 cm. Watch chain speeds. Maintain and fix chains, flights, belting.		May avoid low areas or segregate in storage.	Try to dig during warm part of day if possible. Be extra gentle.	Segregate if amount. Cull noticeable frost damage prior to storing.	Segregate if serious amount. Increase hand sorting on harvest or piler.
POST HARVEST	Cure at 15°. Keep humidity high since weight loss can be rapid.	Cure at 15°. Ventilate at high RH. Lower slowly to storage temp.	Cure at 15°. Ventilate continuosly with humidifier off. Return to normal when dried.	Ventilate and slowly increase temperature to 15°. Check all frquently.	Ventilate. Keep at 8-10°. Reduce humidity to 80%.	Ventilate. Lower temperature to 5-8° quickly.
STORAGE	Store at 6° (Fresh). Store at 8-10° (Process). Store at 4° (Seed). Check storages & crop quality frquently.	A) Ventilate intermittently B) Continuous or intermittent ventilation. C) Intermittent ventilation.	Check all more frequently. Check chip quality (B).	Check all frequently. Check chip quality early (B).	Check frquently. Ventilate till decay dried. Prepare to market early. May not chip. Check early and often.	Check more frequently. Direct more air to worst spots. Seed may not pass.
MARKETING	May vary over extended time, or be rapid.	Try to warm to reduce damage. (B) Precondition. (C) Prewarm to break dormancy.	May have to be moved early.	May have to be moved early. May not chip or fry. Test healing ability of seed potatoes. Test sprouting of seed.	May have to be moved early. May not chip or fry.	May have to be moved early.
POST STORAGE	Clean, repair. Inspect for damage.					Disinfect as soon as possible.

Storage/Crops Types: A. Table stock for the fresh market
B. Processing potatoes, conditions vary according to type and end use
C. Seed potatoes

APPENDIX

GLOSSARY OF FREQUENTLY USED TERMS

The following are statements about the usage of terms in crop production and are not necessarily intended as "definitions".

Active ingredient: That portion of a pesticide formulation that is toxic to pests. Most pesticide products contain only a portion of active pesticide, the rest is carrier. For example: 10G means 10% active ingredient in granular form; 5EC mean 5% active ingredient as on emulsifiable concentrate.

Bacteria: Very small single-cell organisms that may attack plants and cause disease. Soil bacteria aid in breakdown of organic matter.

Banding: Placement of fertilizer or pesticide, at the time of planting, in a continuous band to the side and below the seed.

Broadcast: To spread fertilizer or pesticide over the entire area of the soil surface or the entire crop area prior to planting.

Carrier: An inert material mixed with active pesticide ingredients to make a pesticide formulation. Example: Finely divided clay or talc is used as a carrier in dust forms of insecticides.

Certified seed: Standard seed used by commercial growers normally grown from foundation seed and normally representing the fifth and last generation in the potato seed cycle. Potatoes grown from certified seed are not re-certifiable.

Cultivar: A horticultural classification which means cultivated variety. In most cases cultivars are "man made" as opposed to naturally growing plants. Russet Burbank and Norchip are cultivars of potatoes. The term variety is often used (scientifically incorrectly) in crop production to mean cultivar.

Days-to-harvest: The period of time which must elapse by law between the application of a pesticide and the actual harvest of the crop.

Drift: The undirected and uncontrolled movement of spray mist that occurs at time of spraying.

Drill: To place fertilizer or pesticide with or near seed in the seed "drill" or furrow.

Dust: A finely divided carrier containing a pesticide, usually in low concentration, to be used without dilution.

Elite seed: Certified seed of three classes (Elite I, Elite II, and Elite III) each representing another generation away from the virus free pre-Elite source. Visible disease tolerances for Elite I and Elite II are zero.

Emulsifiable concentrate: A liquid pesticide consisting of active ingredient, solvent and emulsifier that mixes with water to form an emulsion (e.g., diazinon 50 EC). The 50 means 50% of the volume is pesticide.

Fertigation: The process of applying soluble fertilizer materials through the irrigation system.

Fertilizer: Any material added to soil or crops that is a source of plant nutrients.

Foundation seed: Certified seed normally grown from Elite III seed and normally representing the fourth generation away from the pre-Elite virus-free source.

Fumigation: The use of pesticides in a gas form to destroy pests or disease organisms.

Fungi (singular fungus): A large group of simple plants which lack chlorophyll, and that require a source of material to live on. Some are parasitic and attack living plants. Soil fungi aid in breakdown of organic matter.

Germination: 1) The beginning of the growth processes of a seed once it is placed in suitable moisture and temperature conditions. 2) A term applied to the number of seeds that will germinate (given in percentage).

Granular pesticide: A pesticide formulation in the form of relatively coarse particles which is applied dry with a spreader, seeder, or special applicator (for example, Temik 10G).

Green manure: A crop that is grown and plowed down as a source of organic matter for the soil.

Herbigation: The process of applying herbicides through an irrigation system.

Humus: That part of organic matter in the final stages of decomposition which is normally slow to be totally broken down both physically and chemically because of its composition and structure.

Incorporate: To thoroughly mix a pesticide or fertilizer with the soil so that it is uniformly concentrated to a specified depth.

LD 50: Abbreviation for the dose of a pesticide (or other toxicant) that produces a 50% kill of the organism being tested. It is usually expressed as mg per kg of body weight.

Macronutrient: An essential nutrient which is required by plants in large quantity, for example, nitrogen, phosphorus.

Micronutrient: An essential plant nutrient which is required by plants in relatively small amounts, for example, boron, zinc, manganese.

Mycoplasma: Bacteria-like organisms which may cause plant diseases.

Nematicide: A pesticide to control nematodes.

Nematode: A very small worm that lives in the soil. Some species may cause severe crop damage by attacking and living in root tissue. Normal sizes range from 0.8-3 mm (1/32-1/8 in.).

Nutrient: A chemical element that is required for crop growth. There are 16 essential elements for crop growth of which 13 are obtained from the soil. The other three, carbon, hydrogen and oxygen, come from water and air.

Organic matter: Plant or animal residues in varying stages of decomposition. Undecomposed plant material is normally referred to as 'trash' and doesn't become organic matter until it starts to break down.

Postemergence: After a crop emerges from the soil.

Pre-Elite: Virus free potato seed stock used by Elite seed growers to produce Elite I seed. In Alberta, Pre-Elite seed is sold to growers by the Alberta Department of Agriculture from the Seed Potato Program at Olds.

Preemergence: The time after planting seed but before a crop emerges. Many herbicides are applied after planting but preemergent to the crop.

Re-entry time: The minimum time allowed between the time of spraying a pesticide and the time at which the area may be entered by people unless protective clothing and breathing aids are used.

Residue: That portion of pesticide or fertilizer that remains in the soil or on crop plants after application. Amounts of residue decrease with time. Pesticides may leave residues from several hours to several years.

Residue tolerance: The maximum amount of a pesticidal residue that may lawfully be present in, or on, a food product offered for sale. It is expressed in parts per million.

Seed certification: The process of application and field inspection to check for the incidence of specified diseases and ascertain if the level of disease qualifies a seed lot for certification at a certain class.

Normally Elite I planted, produces Elite II, etc.; however, because disease incidence may be above the level specified for that class a seed lot may be "bumped" to another class. For example Elite III (planted) that is planned to produce Foundation may be given Certified class certification.

Seed piece treatment: Chemical treatment of seed to eliminate or reduce organisms which may cause seed piece decay, seedling death or disease in a growing crop. Chemical treatments include fungicidal and insecticidal applications to the seed.

Side dress: To apply fertilizer in the soil along side of a crop row after the crop is established.

Surfactant: A compound which increases the spreading ability of a liquid (emulsifiers, soaps, wetting agents, detergents, and spreader stickers) and aids in the effectiveness of some herbicides and insecticides. Do not use a surfactant unless recommended by the pesticide manufacturers.

Systemic pesticides: A pesticide which is absorbed by and flows through the 'system' of a plant or animal so that the plant or animal becomes toxic to the pest to be controlled. When referring to a herbicide means that the chemical is absorbed by the plant and kills the plant "internally".

Top-dress: To apply fertilizer, by broadcasting, to the entire growing area after a crop is established.

Toxicity: The poisoning ability in speed and severity of a pesticide. The toxicity of a chemical to humans is usually based on its assumed (or known) effect on humans, and its known effect on test animals.

Tuber: Botanically, a swollen underground stem. The potato is a tuber and not, as often thought, a large root.

Tuber unit planting: The process of planting all the seed pieces from one tuber consecutively in a row. They are kept separate from seed pieces of other tubers by leaving a gap between units from one tuber.

Variety: A botanical classification used to group or separate plants within a given species. Broccoli, cabbage and cauliflower are varieties of one species of plant. The term variety is commonly used to mean cultivar (cultivated variety).

Virus: A submicropscopic particle of nucleic acid and protein. All plant viruses are parasitic.

Virus freeing: A process of completely freeing tubers from all known viruses. Also used as a general term to signify freeing from all diesease.

Volatility: The evaporation (release of fumes) of pesticides (or any liquid or solid) after landing on the target plant.

Weed: A plant growing where it is not wanted.

Wettable powder: Dry formulation of a pesticide which is normally mixed with water to form a sprayable suspension (for example, Guthion WP).

Wetting agent: See surfactant.

Wireworm: A small 'wormlike' or 'caterpillar-like' insect that lives in the soil and is the larval stage of a click beetle. These usually white, ivory or tan colored insects have hard, shiny outside coverings and can cause damage to seeds, root crops and potatoes. Normal sizes range from 1 to 2.5 cm in length.

POTATO GRADES

The following descriptions (especially those for fresh potatoes) are offered as a guide only and have no official sanction. Consult the C.A.P.S. act and seed regulations for precise legal descriptions.

Potato growers and packers are required to supply potatoes that meet certain standards: standards set by law or by contractual agreement. All potatoes whether fresh, processing of seed must meet general requirements regarding: varietal characteristics, size, physical condition, freedom from disease, cleanliness, packaging and labeling.

Seed Potatoes. Seed growers and interested commercial growers who want copies of the detailed seed regulations should contact either the Agriculture Canada Food Production and Inspection Branch in the city nearest them or can contact:

Officer-In-Charge
Seed Potato Certificiation
Food Production and Inspection Branch
9820 - 107 Street
EDMONTON, AB T5K 1G2
phone: 420-2800

Current regulations define seed size by weight and the new regulations will specify seed sizes by diameter: however the supplier is obligated to deliver seed as requested by the purchaser. If a buyer requests certain specifications, such as size ranges well below the legal tolerances, then the seed grower should supply seed within the specifications agreed to. Should he not wish to conform to the buyer's request, then the seed grower has the option not to agree to the specifications and perhaps lose a sale.

Seed buyers should be familiar with seed standards as they allow for a wide range in seed weights. Current allowable sizes for seed are from 30 g to 450 g (1 oz-16 oz) - a range far too wide for practical seed cutting. Purchasers more commonly request seed that ranges from 40 g to 300 g. Narrow weight ranges, such as 50 g to 250 g (1 oz-8 oz) would result in much more uniform cut seed lots with relatively few pieces with three and four cut surfaces.

Process Potatoes. The requirments for potatoes delivered for processing are established by the processing company. Dockage is determined at time of delivery either by the processor, or by an independent Agriculture Canada inspector.

Processors require that potatoes meet general physical requirements similar to fresh market potatoes: clean, free from damage and decay. A 50 mm (2 in.) minimum diameter is required by chipping processors; and french fryers require a minimum diameter of 45 mm (1¾ in.) and a minimum length of 75 mm (3 in.).

More importantly the potatoes must meet the company's minimum requirements for processing. The chips or fries produced from a potato lot must be light in color. A french fry processor can manipulate the frying process to vary product color; however, a chip processor has very little control over the color of the final product. Dark chips and fries are produced from potatoes with high sugars.

Fresh Potato Grades. Table potato grades are defined in federal regulations called the Canadian Agricultural Products Standards Act. Alberta legislation provides for grades that differ from federal grades: however, these special grades apply only to potatoes marketed in Alberta. Currently there is an Alberta grade, Alberta No. 1 Small, that allows for small potatoes, 25-50 mm (1-2") in diameter, to be marketed in Alberta, from July 1 to September 15 of each year.

There are four Canadian grades for potatoes: Canada No. 1, Canada No. 1 Large, Canada No. 1 Small and Canada No. 2. The majority of Alberta potatoes are marketed as Canada No. 1 or Canada No. 2.

Following is a summary of potato grades. Contact the Food Production and Inspection Branch for assistance with grade definitions.

Canada No. 1 Potatoes. Canada No. 1 potatoes have similar varietal characteristics: are firm; are not pointed; dumbell shaped or deformed; have well-set skins; are reasonably clean; are free from damage, decay and injury. Round potatoes have a minimum diameter of 57 mm (2 in.) and a maximum diameter of 90 mm (3 in.). The size regulations for long cultivars is somewhat more complicated and packers should become familiar with them. Long varieties have a minimum diameter of 50 mm (2 in.) and a maximum diameter of 90 mm (3 in.); however if tubers are at least 90 mm (3 in.) long then they may have a diameter of 45 mm (1¾ in.); BUT in all cases, Canada No. 1 (long) potatoes must have a diameter of at least 57 mm (2 in.) in at least 60% of the lot by number.

Canada No. 1 Large potatoes have a minimum diameter of 75 mm (3 in.) and a maximum diameter of 115 mm (4 in.). Canada No. 1 Small potatoes have a minimum diameter of 38 mm (1 in.) and a maximum diameter of 57 mm (2 in.). Both of these grades comply with the other requirements of Canada No. 1 potatoes.

Canada No. 2 potatoes are similar to Canada No. 1 potatoes in their general appearance; however they differ in size. They have a minimum diameter of 45 mm (1¾ in.) and a maximum diameter of 115 mm (4 in.) but have a diameter of not less than 50 mm (2 in.) in at least 75% of the lot by weight.

The regulations provide for *New Potatoes* that are shipped by September 15 of the crop year. They must comply with other Canada No. 1 regulations; however, they can be smaller. Round and long potatoes shipped

before September 15 can have a minimum diameter of 48 mm (1⅞ in.).

The regulations recognize the difficulty in fitting biological specimens, that tend to be variable, into rigid categories and therefore have allowable tolerances. Generally lots may contain undersized-oversized potatoes up to 5% by weight; and they allow for specified amounts of tuber defects.

CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in:	
LINEAR			
inch	x 25	millimetre	(mm)
foot	x 30	centimetre	(cm)
yard	x 0.9	metre	(m)
mile	x 1.6	kilometre	(km)
AREA			
square inch	x 6.5	square centimetre	(cm^2)
square foot	x 0.09	square metre	(m^2)
acre	x 0.40	hectare	(ha)
VOLUME			
cubic inch	x 16	cubic centimetre	(cm^3)
cubic foot	x 28	cubic decimetre	(dm^3)
cubic yard	x 0.8	cubic metre	(m^3)
fluid ounce	x 28	millilitre	(mL)
pint	x 0.57	litre	(L)
quart	x 1.1	litre	(L)
gallon	x 4.5	litre	(L)
WEIGHT			
ounce	x 28	gram	(g)
pound	x 0.45	kilogram	(kg)
short ton (2000 lb)	x 0.9	tonne	(t)
TEMPERATURE			
degrees Fahrenheit	($^oF - 32$) x 0.56 or ($^oF - 32$) x 5/9	degrees Celsius	(^oC)
PRESSURE			
pounds per square inch	x 6.9	kilopascal	(kPa)
POWER			
horsepower	x 746	watt	(W)
	x 0.75	kilowatt	(kW)
SPEED			
feet per second	x 0.30	metres per second	(m/s)
miles per hour	x 1.6	kilometres per hour	(km/h)
AGRICULTURE			
gallons per acre	x 11.23	litres per hectare	(L/ha)
quarts per acre	x 2.8	litres per hectare	(L/ha)
pints per acre	x 1.4	litres per hectare	(L/ha)
fluid ounces per acre	x 70	millilitres per hectare	(mL/ha)
tons per acre	x 2.24	tonnes per hectare	(t/ha)
pounds per acre	x 1.12	kilograms per hectare	(kg/ha)
ounces per acre	x 70	grams per hectare	(g/ha)
plants per acre	x 2.47	plants per hectare	(plants/ha)

INFORMATION SOURCES FOR POTATO GROWERS

Information or Assistance Required	Contact	Address & Phone
Licensing, marketing, seed potato sources	Bernie Butterwick, Secretary/Manager	Alberta Potato Commission Suite 244, Stockman's Centre 2116 - 27 Avenue, N.E. Calgary, AB T2E 7A6 291-2430, 291-2432
General potato production information.	Clive Schaupmeyer, Potato Specialist	Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta T0J 0J0 362-3391
Pre-Elite seed, potato seed production information.	Jim Letal, Manager, ASPP	Alberta Seed Potato Program Box 10, Olds, Alberta T0M 1PO 556-428?
Seed certification, inspection of farm for seed production, seed regulations.	Gay LePage, Officer-In-Charge	Potato Certification Program Agriculture Canada Food Production & Inspection Branch, 9820 - 107 Street, Edmonton, Alberta T5K 1G2 428-2800
Potato storage design	Dennis Darby, Farm Structures Engineer	Alberta Agriculture Service Center, Lethbridge, Alberta T1J 4C7 329-5114
Disease control	Dr. Ken Mallet, Plant Pathologist/ Storage Specialist	Alberta Horticultura Research Center, Bag Service 200, Brooks, Alberta T0J 0J0 362-3391
	Jim Letal, Plant Pathologist	Regional Crops Laboratory Provincial Building Olds, Alberta T0M 1P0 226-8421
	David Sippell, Plant Pathologist	Regional Crops Laboratory Box 7777 Fairview, Alberta T0H 1L0 835-2291
Insect control	Dr. Ulf Soehngen, Entomologist	Alberta Horticultural Research Center, Bag Service 200, Brooks, Alberta T0J 0J0 362-3391
	Michael Dolinski, Entomologist	O'Donoghue Building, 7000 - 113 Street, Edmonton, Alberta T6H 5T6 427-5339
	Entomologist	Regional Crop Laboratory Box 7777 Fairview, Alberta T0H 1L0 835-2291
	Jim Letal Plant Pathologist	Regional Crops Laboratory Provincial Building Olds, Alberta T0M 1P0 226-8421
	Marilyn Steiner, Entomologist	Alberta Environment Centre Bag 4000 Vegreville, Alberta T0B 4L0 632-6761
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